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French soldiers preparing barbed wire entanglements in the first line of trenches

WINTER WORK ON THE BATTLE FRONT

Economic Industrial Applications of Electricity*

A Potent Means for Conserving Fuel and Human Energy

By Norman T. Wilcox

As my experience in recent years has been largely commercial as well as engineering there are some things that particularly appeal to me. I have been particularly impressed by the development of higher efficiencies of production and consequent lowering of ultimate costs resulting from the application of electricity to manufacturing operations; also by the great opportunities offered by the application of electricity in reducing human labor, both in the home and elsewhere, with its consequent improvement in human efficiency.

The suggestions I have to offer here tonight are not intended to be needlessly technical, but are made with the intention of pointing out some real practical applications which are already being used to a considerable extent and which, if properly appreciated, will materially aid in the attainment of great economy.

In the coming years of sharp world-wide competition, the aggregate of such efficient application will mean much in affording all of our committees the advantage so necessary and so much desired for the coming years. This being the case, it is important that each and every citizen should appreciate his personal responsibility and do his individual part in attaining higher efficiencies in all lines of endeavor.

Electricity is one of the greatest agencies in attaining this result. It is much easier to sell power to mill people and others today than was the case even a few years ago.

INDUSTRIAL AND DOMESTIC SERVICE

The application of industrial and domestic devices for using electricity is proving advantageous, as is evidenced by the enormous sale of domestic devices. The saving of labor to lighten the duties of the housewife, the general improvement of home service, and the comfort which results from the attaining of greater efficiency in the home, results from the use of electric energy. The electric "Mary Ann" does not strike for higher wages, stays in afternoons and evenings and sticks to the job day and night, 365 days in the year, thus saving much nervous energy.

The increases in production due to the more regular speed where electric drive is used, materially increases quality as well as quantity of production. In textile mills this increase has been found to be from 3 to 20 per cent., the latter, of course, being an exception. In addition to the absolute increase in production is the fact that there are materially less rejects due to faulty work, so that the addition to net profits resulting from the use of electric power is a very material one. That this advantage is a very real one, and now appreciated by manufacturers, is typically demonstrated by the experience of textile manufacturers in the city of Lowell, Massachusetts. Some 14 years ago the Merrimac Mill at Lowell had a water wheel driven, 300 kw. alternating current generator driving four or five motors which operated looms and similar textile machinery. This was the only alternating current motor drive in the city which was using approximately 100,000 h. p. for manufacturing purposes.

Today 80 per cent. of the power driving the textile machinery in Lowell is alternating current derived either from central station or from very large plants at the mills. If the central station plant had been equipped with turbine generators of the sizes and efficiencies now obtainable, it is quite likely the major portion of this drive would now be supplied by the central station. This in spite of the fact that considerable steam is required for auxiliary operations.

Only those of you who have had occasion to check such matters carefully can realize how variable are the costs in the ordinary plant that is depending upon men who have not had the experience or means to enable them to properly check up operating expenses.

I personally know of one case of a large steam electric generating plant which had been carefully systematized and operated for a long period under this method. The plant made a careful check in boiler and engine rooms every 6 hours and 12 hours and, of course, took the total for the 24 hours. The labor employed was exceptionally high class, both in the boiler room and elsewhere, and yet, if the check system was given up for ten days, there was just about 10 per cent. loss in the fuel economy. Of course, this proportion would not be obtained progressively for a longer period. However, this result simply shows the importance of careful and continuous attention to detail and of having a high class, high salaried force to insure economical results.

It is obvious that isolated plants, especially the average one, cannot operate so as to conserve fuel and other resources as can the central station. We all appreciate that gasoline is getting scarce and the truck of today is using a relatively large amount of this form of energy for the work done. There seems to be much doubt as to where the supply of fuel is coming from in the future when existing supplies are exhausted. The new plan that has recently been discussed of offering service to electric trucks in the city, which will include the garage, ordinary service and renewals of batteries, making the charge for energy and the total service on a flat rate basis, should be the means of enormously increasing the use of electric energy, and incidentally the means of saving much of the natural oil product which is being used in a grossly wasteful manner in the generation of power and to drive these machines.

Here in Chicago there is an immense number of electric trucks which should use electric drive that would result in a tremendous saving of natural supplies of all fuel.

ECONOMY OF ISOLATED PLANTS

The advent of great central station generating plants has brought about the development of organizations employing the most competent and highest priced technical talent, both for the designing and the operation of these plants.

Compare, if you will, the coal consumption of the ordinary small plant with its comparatively inefficient and very poorly paid operating force, and with a coal consumption of anywhere from 4 to 12 or 15 pounds, or more, per kilowatt hour of equivalent output, with the economies attainable from a large unit steam turbine plant, some of the large units showing an economy of as low as one pound of coal per kilowatt hour.

As a result of these developments, the central station electric supply plants and similar utilities which have been dedicated to public service, have been able to progressively reduce the cost of both energy and light to the ordinary citizen for use in his home. This in spite of the constantly rising cost of almost all other commodities. Further broadened use and development of public service agencies will result in continued advantages to the public.

Although big investments for expensive and large distributing systems are necessary to get this energy to the customer, is it not the part of patriotism to encourage these developments and to make possible these great economies in the saving of fuel which can be attained only in this manner?

It would seem that true conservation calls for hearty co-operation on the part of every engineer in order that we may conserve for future generations the priceless supplies of coal and oil fuel which nature has bestowed upon us and which in the not distant future must come to an end. Should not every conscientious engineer labor to bring about a result so advantageous to the country as a whole?

THE ELECTRIC VEHICLE

Electric vehicles, especially in large and comparatively level cities, have a wonderful possibility of conserving much natural energy now wastefully used in the form of gasoline.

The development of the electric truck and of methods of use allowing of a definite charge per month for the use of batteries, electric energy, etc., is a forward step in the direction of greater efficiency and true conservation.

The Bush Terminal in New York uses 12,000,000 kilowatt hours per annum for charging of electric trucks alone. This is some indication of the possibilities of this large and practical field for the use of electric energy.

REFRIGERATION

At first thought the average person would not realize that electric power as applied to refrigeration is a development in the line of greater efficiency. Yet we must recognize that artificial refrigeration results in the conservation of much perishable food and allows of a more even distribution of these products over the whole year.

The application of electric energy for this purpose results in a great saving of fuel which, in future generations, will be almost priceless. The improvement in the quality of ice distributed for dometsic use results in a conservation of health and increase of comfort, which is also in the line of true efficiency.

In Chicago alone twenty-six plants indicate that the public understands and appreciates the advantages of this application.

ELECTRO-CHEMICAL APPLICATIONS

The use of electric power for electro-chemical work, which is a comparatively new field and doing much at present, affords even greater promise for the future.

The formation of the recent joint committee of the American Electro-Chemical Society and the Electro-Chemical Division of the Power Sales Bureau of the N. E. L. A. will doubtless be an effective means for increasing the efficient results of this development.

ELECTRIC STEEL FURNACES

Outside of the steel trade few people appreciate the rapid growth in the use of electric furnaces for the production of the highest grades of steel and steel castings.

This growth has resulted from the efficiency of electric power and has for the most part occurred within the last five years, the greater portion of the increase occurring in the last year or two.

Up to March 1, 1917, at least 158 steel-making electric furnaces had been contracted for or were at that time in actual commercial service in the United States. These furnaces if operated twenty-four hours a day, six days in a week, would have a total capacity of 1,000,000 tons of steel per annum.

Ten years ago, or less, there were but a few tons of electric steel produced in this country. The production of a million tons of steel made from cold scrap would represent at least 600,000,000 kilowatt hours per annum. A large portion of this energy should be supplied from public utilities, and should contribute its part in widening the use of public service investments, with consequent benefits to the communities served.

Because of its uniformity, greater freedom from segregation and its greater homogeneity, *electric* steel is somewhat higher in tensile strength and elastic limit than steel made by other processes. Owing to its greater density the electric steel shows a marked resistance to fatigue.

No doubt the discovery that the best crucible quality steel can be made in the electric furnace, and the further fact that crucibles have become almost prohibitive in price, has contributed greatly to a rapid realization of the great practical value of the electric furnace.

BASIC OR ACID PROCESS

In the open-hearth furnace the melting is accomplished by a flame, which, under the best conditions, is oxidizing in its nature.

In the basic open-hearth process, carbon, phosphorus, silicon, manganese and some sulphur are removed from the bath. In the acid open-hearth process only carbon, silicon and manganese are removed.

Where the heat is produced by an electric arc, it is possible to melt and refine a charge of metal in a neutral and reducing atmosphere free from the foreign materials incident to the use of an air blast.

In an electric furnace the refining may be commercially carried out to a much higher degree of perfection than is possible with other methods. All methods of steel making, except the electric furnace, have quite definite and limited fields of use. On the other hand, the electric furnace can be used to produce steels equivalent to any of those obtained through other processes.

Looking at the situation broadly it may be stated that where the electric furnace is used for melting and refining, and in cases where superiority and uniformity of product is essential, the electric furnace competes successfully with the open-hearth furnace. This is because the increased cost due to the use of electric power for melting is offset by the advantages of refining which are peculiar to the electric furnace.

A crucible furnace does not make any better steel than can be made commercially by the use of a properly designed electric furnace and is handicapped by the necessity of carefully selected material for use. The use of the electric furnace makes the manufacturer, to a great extent, independent of the high labor costs and high cost of the extra selected materials necessary for the production of the best quality crucible steel.

*A paper presented before the Western Society of Engineers, and republished from the *Journal* of the Society.

It may be of interest to note that for average conditions, good raw material and 24-hour operation, 600 kilowatt hours per ton of melted metal should be sufficient for the manufacture of ordinary high grade steel. Carbon steel may require some less and some alloy steels may use quite a bit more. Less than 24-hour operation will somewhat increase the kilowatt hours required per ton of metal.

If the melted metal is not poured quite close to the furnace but is carried some distance before it reaches the mold, extra energy will be required to offset the heat losses during the period that elapses before the metal is poured. The kilowatt hours may also be increased as a result of poor organization of foundry force or as the result of lack of skillful and well-directed operation.

In some cases the same furnace may be used in the production of high grade cast or malleable iron. Owing to the low melting point, less energy is required for cast iron than is necessary in the production of steel.

Small furnaces have been developed even in the multi-phase type down to capacities as low as one-half ton of metal per heat. A furnace of this size will require from 100 to 125 kilowatts of capacity and when operated multi-phase will run on a power factor of approximately 90 per cent. The larger furnaces as now installed, for most efficient operation require approximately 250 kilowatts of capacity per ton of metal per heat.

In order to obtain the desirable rapid melting down, the transformer connections are now arranged for more than one voltage and furnaces so arranged that after extra heat is absorbed by the cold metal the voltage may be reduced and the furnace refractories saved from undue wear. This is important.

As many, if not most, of the small steel furnaces, as well as some of the larger ones, can be so operated as to keep off the peak, the furnace load is an attractive one.

Smaller furnaces will, no doubt, be eventually used in many small factory foundries. Small or irregularly operated furnaces will, of course, require more energy owing to the losses due to radiation, heating up the furnaces, etc., but on the whole it may be said that the electric furnace is another one of the modern instruments which are broadening the use of electric energy and contributing their share to the ultimate efficiencies.

Load factors claimed have no doubt been higher than attained in actual operation. With a 30-minute demand and a single unit plant a 45 per cent. load factor, even when the furnace is operating 24 hours a day, is the exception—not the rule. Where a greater number of units are used the diversity effect may result in a better load factor.

Power factors and energy for a furnace load should always be rated and measured on the primary side of the supplying transformer, and operating data should be based upon this condition—not on data obtained from the secondary side of the transformer. This procedure is necessary in order to avoid troubles incident to the use of instruments placed in the arc circuit.

The quality and kind of scrap material used will have a marked effect on the kilowatt hour consumption per ton of product. Selected materal will afford selected results. If high grade, low phosphorus, low sulphur scrap is used, less energy will be required and the fixed charges, as well as other charges such as labor, will be materially less than if inferior materials are used.

Owing to the superiority of the arc furnace over the crucible method of producing high grade steel, and owing to the further fact that the arc furnace does not necessarily require the highest grade of raw material, as does the crucible method, we may confidentially except the crucible method, generally speaking, to become a thing of the past because it is becoming an economic impossibility.

As electric furnace practice is better understood and costs of furnaces become lower in price, we may expect a more general and extensive adoption of the small sized furnaces in many manufacturing plants that have not as yet seriously considered this plan of operation as a practical possibility.

The operation of the electric furnace, especially where selected material is used, is ideally simple and satisfactory and should result in increased efficiencies.

Electric furnaces cannot be expected to take the place of the ordinary cupola, such as is used for the making of common grades of cast iron. However, we should not lose sight of the fact that the electric furnace is the only apparatus which will successfully produce all grades of material from and in the same furnace. These products range from superior quality cast and malleable iron up through the list of various grades of steel, including the finest grades of crucible and tool steels.

FURNACES FOR NON-FERROUS METALS

The electric furnace will also be used extensively in the melting and treatment of other metals, such as red brass and some alloys.

There are several of this type of furnace now in operation in this city. It will be noted that all of these operations are comparatively recent developments, which accounts for the fact that this type of apparatus is not more generally used.

There are so many possibilities in the increased and broadened used of electric energy that it is not worth while to further enumerate these applications at this time. Broadly speaking, the greatest efficiencies in the conservation of coal, human energy and human comfort are to be obtained by the broadest possible use of electric energy and service such as is now possible. I am, therefore, recommending the possibilities of these applications and their resulting economies for your consideration during the coming years, and I believe that a careful consideration of the possibilities of the wide and economic application of electric energy will result in further interest on the part of all who are anxious to make our cities and the country at large still more satisfactory as a place of residence for the average human being.

Spark Lengths In Gases and Vapors

ALTHOUGH the electric discharge through gases has been the subject of many varied investigations, most of the experiments have been limited to the air and to the other constituents of the atmosphere, both the common and the rare. The discharge through hydrogen has especially interested the physicist and the radio-telegraphist; the chemist has studied rather the reactions accompanying the discharges through gases than their physical phenomena. Natterer determined spark lengths in various gases in 1889 and found it difficult to co-ordinate the physical and chemical phenomena, as was to be expected. What is more or less ordinary temperature and pressure for the so-called permanent gases may be extreme conditions for vapors, and it is not easy to realize corresponding experimental conditions. Taking up these difficult researches a few years ago, Mr. Robert Wright of the University of Glasgow (Transactions of the Chemical Society, 1917, pages 643 to 649), first attempted to compare vapors at their boiling points with air at the same temperature; but he had to abandon this plan for several reasons, the condensation of vapors on the electrodes in the first instance. He therefore decided to keep the two spark gaps to be compared, of air and of the gas or vapor under test, at the same temperature, so as to have the same number of molecules per unit volume. That the spark length depends on the number of molecules in the gap was understood. Heating a gas has no effect on the spark length, provided the number of molecules per cubic centimeter be kept constant. Thus when the spark is produced in a closed vessel, the volts required to produce a spark are independent of the temperature; when the vessel is left open, so that the gas can expand, rise of temperature increases the length of the spark corresponding to a certain potential difference; lowering the gas pressure has the same effect as raising the temperature. Wright found in his experiments that a gap of 20 mm. at 100 deg. C. corresponded with a gap of 15 mm. at 18 deg., and a gap of 20 mm. at 183 deg. with one of 5 mm. at 18 deg. The electrodes of his standard air gap are brass spheres, 5 mm. in diameter, fixed on 3-mm. rods; they are adjustably mounted, with the aid of corks, in a vertical glass tube, 15 mm. internal diameter, surrounded by a vapor jacket. The tube containing the gas or vapor under test is similarly arranged, and the two tubes are electrically in parallel with an induction coil. There are, in fact, three spark gaps in parallel, the third gap serving for variation of the potential. At the beginning of an experiment this third gap is almost closed, and its electrodes are then moved apart until a spark crosses one of the other gaps. The apparatus had to be constructed so that it could easily be taken to pieces to clean the electrodes, especially when the vapors were decomposed by the sparks. The observed spark lengths were not very concordant; differences of 10 per cent. and more were frequent, and the spark length corresponding to a 20-mm. air gap was not two-thirds of the 30-mm. air gap, as it ought to have been, if the potential and spark-length curves were parallel. Carbon dioxide, *e. g.*, proved a better insulator than air at low potentials, but a better conductor at high potentials. On the whole, however, an increase of molecular weight was accompanied, in a series of comparable substances, by an increase in insulating power (decrease in spark length). Thus methane CH_4, methyl chloride CH_3Cl, methylene chloride CH_2Cl_2, chloroform $CH.Cl_3$, carbon tetrachloride CCl_4, gave, at 100 deg. C., with an air gap of 30 mm., sparks of 29 mm., 24 mm., 9 mm., 5 mm., 1.5 mm., respectively and with an air gap of 20 mm. sparks of 20 mm., 16 mm., 6 mm., 3.5 mm., 1 mm. Similar figures were found for the halogen derivatives of ethane ((the ethyl chloride, bromide, iodide), for homologous alcohols, and for substances like CO_2, SO_2, CS_2, H_2S.—*Engineering.*

Problems Relating to Intercommunication Between Wireless Stations

IN working in the tropics it was noted that when the two stations were separated by a hill, communication became impossible at night although it was good by day. It is concluded that waves can bend round the surface of the ground better by day than by night. This conflicts with the requirements of the theory of Fleming, which postulates a bending of the rays away from the earth in the day-time, and corroborates the theory of Eccles. Tests made between Noesanivé (Ambon) and the warship *Tromp* stationed in the northern bay of the Island Ceram showed this feature, and it is calculated that during daylight transmission the waves of 600 m. length were bent into a circle of radius one-quarter of the earth's radius. Other tests showed that it is possible to bend the wave to a radius as small as one-sixth of the earth's radius. One would expect even sharper bending to be possible with greater wave-lengths, so that waves are without doubt able to follow the curvature of the earth in the day-time. At night this bending becomes impossible, and stations at any appreciable distance apart can only communicate by waves reflected down from upper layers in the atmosphere. Allowing for the variable transmission and reception intensities at various angles to the vertical it is shown that the reception by the reflected waves will improve rapidly to a maximum as the receiving station recedes from the sending station and then decrease again slowly. If the emitted waves are undamped interference may be produced at a receiving station between waves reflected once at the upper reflecting surface and waves reflected back by the earth's surface and reflected a second time from the upper surface. It follows that if this is the case the strength of the received signals will depend on the resultant signal produced by the superposition of waves reflected various numbers of times before they reach the receiver. If the difference between the paths traversed by two such waves is an even number of wave-lengths they will add their effects and the signals will be strong. If, however, the wave-length is only slightly altered, *e. g.*, so that the same difference shall be an uneven multiple of the half wave-length, the effects of the two waves will be subtracted and the signals will be weak. This dependence of the strength of signal on small variations of the wave-length has been noticed by Austin and de Forest. A calculation is given to show that according to this theory the signal may change from a maximum to a minimum intensity for a variation of only 0.3 per cent in the wave-length. An extension of this reasoning leads to a method of accurately determining the height of the Heaviside reflecting layer. The reflection will be best and the transmission over long distances will be the best when the reflecting layer is undisturbed, *i. e.*, at night-time. The theory of propagation by repeatedly reflected rays is used to explain the occurrence of silent zones at a series of distances from the sending station and of "freak" signals at unexpected distances. Using observed distances of these silent zones it is calculated that the reflecting layer must be about 200 km. above the earth's surface.—Note in Science Abstracts on an article by C. J. DE GROOT in *Jahrb. d. Drahtl. Tele.*

Acid Resisting Metals

THE iron alloys which have answered in the manufacture of acids, partly replacing stoneware, are ferro-chrome and silicon-iron. Ferro-chrome is not, or but little, attacked by sulphuric acid and nitric acids, weak or strong, not by glacial acetic acid, but readily attacked by hydrochloric acid. The chief Si-Fe alloys are "tantiron," "duriron" and "ironac." These alloys resist strong and weak sulphuric and nitric acids. The composition of tantiron has been given as: Si, 14 to 15; Mn, 2 to 2.75; C, (graphite) 0.75 to 1.25; S, 0.05 to 0.15; P, O.05 to 0.1 per cent; density, 6.8; melting point, 2 550 F.; tensile strength, 6 to 7 tons/square inch. Tantiron will not stand high internal pressures unless strengthened. Duriron consists of Si, 14 to 14.5, C (total), 0.2 to 0.6; Mn, 0.25 to 0.35; P ,O. 16 to 0.2; S, under 0.05 per cent; density, 7.0; melting point, 2 500 to 2 550 F.; compression strength, 70 000 lb./square inch; tensile strength, 25 per cent less than cast iron.

Ancient Clock Jacks

Curious Figures That Formerly Decorated Clock Towers in England

An accompanying drawing shows the very old clock-jacks on the tower of St. Mary steps, Exeter. It might perhaps be a better drawing. The reason why it is not is that the clock and those quaint figures are at so great a height that the difficulty of seeing their details is rather distressing.

This group is of bronze, and is said to date back to the time of Henry VIII. Indeed, the seated figure is generally supposed to be intended for him. I do not think it to be a good likeness; while, as for the men-at-arms on either side, I have never seen anything quite like them, except perhaps in the pictures of old-time Japanese warriors.

These grisly creatures strike the quarters on bells at their feet, while the seated figure bends forward with every stroke of the hour.

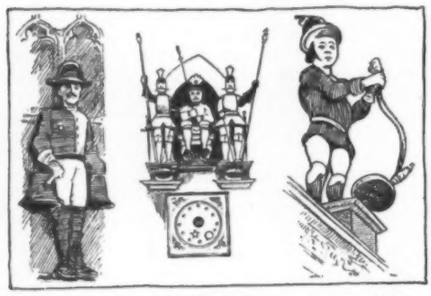
In the neighborhood of St. Mary steps, which is that of the old Exeter slum still called "Exe Island," although it is an island no longer, the seated effigy has generally been known as "Matty the Miller," from a worthy who lived close by and was more punctual than the clock itself.

Matty was at last gathered to his fathers, but, according to the old rhyme:

> "The people around would not believe
> That Matty the Miller was dead;
> For every hour, on Westgate tower,
> Matty still nods his head."

From this it would appear that these picturesque clock-jacks were formerly on the West Gate, one of the demolished gates in the old city walls.

Among the surviving clock-jacks, those quaint little effigies over the interior of the south porch of Norwich Cathedral are well worth seeing. Unfortunately they



CURIOUS CLOCK-JACKS. (Left) An old carved clock-jack figure, of unknown origin, in the church of Wimborne Minster, Dorset. (Centre) The group of bronze clock-jacks on the tower of St. Mary Steps, Exeter. (Right) The clock-jack in Minehead Church, Somerset.

are not in working order. They date from the time of James I., but the clock has disappeared.

The little figures are of painted wood, and are nineteen inches high. Their doublets are painted red, their baggy breeches in blue and white bands, while their stockings are flesh-colored. They once struck the quarters, turning round on pivots for that purpose.

On the platform on which they stand are painted the Latin inscriptions, "Me Boni hodie?" and "Ah! diem perdidi." That is to say, "Have I done any good to-day?" and "Ah! I have lost a day."

It is about a hundred years since the clock was displaced and these jacks put out of commission. This seems to have been done because the sight of them was so popular that large numbers of people visited the Cathedral for no other purpose. Both clock and figures were sold, but these little mannikins were afterwards recovered.

A queer little clock-jack not often noticed is that which is now placed on the rood-screen of Minehead Church, Somerset. It was once on the tower. Like those of Norwich Cathedral, it has long since retired from business.

Perhaps the finest specimen of a clock-jack in England is that excellently carved oaken figure of a man in armor which is to be seen within the great church of Southwold, in Suffolk. It stands 3 ft. 11 in. high, and represents a man-at-arms clad in the armor of about 1490-1510.

The figure is painted in russet color, heightened with gilding. A sword or scimitar is in his left hand, and in his right is a battle-axe, with which he strikes a bell.

Unfortunately this picturesque figure no longer strikes the hours. He was removed from the tower a long time ago and placed in an alcove by the vestry, where he is made, by the parish clerk pulling a string, to

Carved oak clock-jack, now in the vestry of Southwold Church, Suffolk.

strike the bell as the officiating clergy emerge from the vestry at the beginning of service.

Near Southwold, in the venerable church of Blythburgh, is another clock-jack of the same period, but in a battered condition, having lost the lower part of the left arm, and being generally the worse for wear, consequent upon having been removed from the church for many years and knocking about in various places.

"Peeping Tom" of Coventry, which may originally have been a clock-jack figure.

The battered old clock-jack preserved in the church at Blythburgh, Suffolk.

It was at last returned to Blythburgh Church after the partial restoration of 1884. The figure represents a venerable and bearded warrior, well beyond the present military age.

At Wimborne Minster, down in Dorset, where the great church is a veritable museum of antiquities, including chained books—the largest collection of chained and safeguarded books in England, some 240 in number, collected together in 1686—muniment chests, and so forth, there is not only that fourteenth century astronomical clock mentioned some time since, but also high up on the exterior of the western tower, in one of the belfry windows on the north side, a little figure of a clock-jack. It is carved and fashioned very much after the style of a French *gendarme* of the old *régime*, with long thigh-boots, smart coat, and cocked hat. It strikes the quarters on two bells, one on either hand. No one seems to be conversant with the history of this little figure.

A quaint rattling old bag of tricks is housed in the belfry of the old Corn Market at Launceston, Cornwall. They came from Hexworthy, in Lawhitton, two miles or so to the south of the town.

* * * * *

Time has dealt with exceeding severity with the once-numerous company of clock-jacks. They belonged to an age which took a greater delight in this sort of thing than does our own. Besides those I have mentioned there are not many others left.

I seem to remember a set of jacks, in going order, still at Northampton, on the tower of either St. Giles's or St. Peter's Church. Perhaps a Northampton reader who may feel interested in this subject will supply particulars.

There are those who consider that the familiar figure of "Peeping Tom," which still peers forth from his alcove in Hertford Street, Coventry, was really, once

Quaint clock-jacks of painted wood in the South porch of Norwich Cathedral.

upon a time, a clock-jack figure, but from where it was removed no one seems prepared to say.

Of course, the generally-received opinion is that this poor old battered thing, with a kind of Dan Leno smile, represents the famous mythical tailor, that "low churl, compact of thankless earth," as Tennyson styles him, who peered forth upon Godiva when, with her golden hair hanging down her back, she rode along Coventry's streets in what Trilby would style "the altogether."

If this surviving figure be really intended for Peeping Tom, then all I can say is that it must represent the tailor as he was caught coming nome from a pageant. I have observed many strange sights, but never have I seen a tailor dressed like this in business hours. He would not dare do it.

So possibly this is a clock-jack after all, but the poor old thing's mutilated arms render this a very speculative theory.

There is, at any rate, one specimen of a revived clock-jack group to be seen. It is a familiar sight of late years to those who tour that picturesque road between Dorking and Guildford, being situated by the wayside in the little village of Abinger Hammer. Two figures are placed in a kind of combined clock-tower and tabernacle, and perform upon bells. Underneath, as I recollect it, is the inscription, "By me you know How fast to go."

Abinger Hammer, which was originally a hamlet of Abinger village, more than a mile away on the hill-top, is now much larger than the original. It arose from beside the old "hammer-ponds" of the long-extinct iron smelting works.

The clock-tower, bells and clock-jacks were erected a few years ago by Lord Farrer, of Abinger Hall, and

are, more or less, a free copy of the famous "Giants of St. Dunstan's," which used to strike the quarters in Fleet Street until they were removed in 1830, having occupied that position since 1671.

They are now at Lord Aldenham's villa of "St. Dunstan" in Regent's Park, having been purchased on their removal from Fleet Street by the Marquis of Hertford at a cost of £210.

"St. Dunstan's" is, of course, familiar nowadays as the hostel for soldiers blinded in the war.—WAYFARER in *The Autocar.*

The Rainbow*

By Otto Klotz

PERHAPS some elementary statements about the rainbow may be of interest to some of the readers of the *Journal*. Theoretically no two persons see the same rainbow. The rainbow is a color sensation, and has as little substance as the colors flashed from a diamond. The position and height in the heavens of the rainbow is a matter of relative position of the sun, the observer and the minute drops of water in the air in which the rays of the sun are twice refracted and once reflected, as seen in the accompanying figure (Fig. 1). When a ray of white sun-light strikes the globule it is refracted and as rays of different wave-lengths have different indices of refraction, the white ray, which is simply a bundle of many rays of different wave-lengths, is broken up into its constituent parts, and some of these when they reach the eye produce the sensation of color. For simplicity, of what is intended to be conveyed, we shall confine ourselves to a single ray of the bundle, say the ray that gives us the sensation of red. The ray *S M* (Fig. 1) strikes the globule at *M*, here it is refracted at a certain and definite angle with the radius *O M* to *N*. Here part of it passes out of the globule and is lost to us while another part is reflected again with a definite angle *O N R* equal to *O N M*. At *R* it emerges from the drop and is again refracted into the air, suffering the same refraction as when it entered, and reaches the eye at *E*. Now every one of the myriads of globules of water that are in the air when a rainbow is seen, sends out such refracted rays and one would imagine a blaze of color as the result, but, of course, such can not be the case for, as we have seen, if we follow any particular ray, one that is to reach the eye after it has been twice refracted and once reflected we shall find that it must have a definite position in the sky with reference to the observer and the sun. The ray that we are considering makes an angle of 42 degrees with the line joining the observer and the sun. The distance that the globule is away from the observer is immaterial, as every one knows when he sees a rainbow when using a lawn sprinkler. It is the angle spoken of above that is the governing factor. Now having this angle fixed in our mind, it readily follows that every globule situated at this angle will give us a ray of this particular color (red). Hence we see an arc in the heavens and which is the base of a cone having its apex at the eye and making an angle of 42 degrees with the axis. This gives the fundamental idea of the rainbow, for any time of the day and for any position of the sun. On account of the distance of the sun, we may consider all its rays parallel, and parallel to the line, observer—sun. To still further impress this fundamental, imagine a rod to connect the sun with the observer and let it be produced and serve as an axis, *C E S* (Fig. 2); at the eye imagine a cone to project *R E P* (Fig. 2), with its surface making an angle of 42 degrees with the axis *C E S*. We have hence a rigid system which serves us for all rainbows, and this rigid system is movable at the position of the eye, one end of the axis pointing to the sun. As the sun goes down the rainbow goes up, *i. e.*, the visible arc is increased until at sun-rise or sun-set we have a semi-circle, the greatest arc possible on the prairie; as the sun goes up the arc goes down, so that when the sun reaches an altitude of 42 degrees the rainbow disappears on the horizon. There can be no rainbow at or about noon in our latitude during the summer months. If we had taken another ray with a different index of refraction the reasoning would have been just the same, but the angle of our cone would be a little different. For violet, which is at the other end of the spectrum, the angle would have been 40 degrees, *i. e.*, at a less altitude, and hence we find violet at the inside of the bow. Some years ago in an address, I gave as a simple mnemonic to remember the order of the colors in the rainbow, for I find that few people know it, although they have seen rainbows scores of times, the word "Ivor," signifying "inside violet, outside red."

When viewing a rainbow one always has his back to the sun, and each observer is in the line of the center or middle of the bow seen. No two persons see exactly the same bow. When a second rainbow is seen above the brighter one, it is due to two reflections within the globule, in consequence of which the order of the colors is reversed, *i. e.*, the red now forms the inside band and the violet the outside one.

The Journal of the Royal Astronomical Society of Canada.

So much for the rainbow in the sky; but at times there are seen "ground-bows." These are seen in fields covered with gossamer of spider webs and dew, as many will recall having seen especially on fallow fields and commons. In *Nature* of March 2, 1916, Mr. A. E. Heath describes very well by word and diagrams one seen by him. The form of the bow on the ground follows immediately by applying the above rigid system of cone and axis. We find that the form must be a conic section —the intersection of the cone with the ground—and,

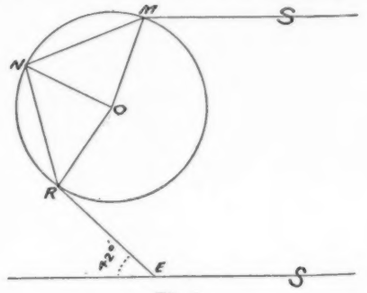


Fig. 1

hence, may be a circle, an ellipse, a parabola or a hyperbola. To give a circle about one's feet the sun would have to be directly overhead, *i. e.*, in the zenith, and the circle would have a radius of about five feet, assuming the eye at 5½ feet above the ground. As the sun declined from the zenith the form would change to an ellipse becoming more and more elongated until at an altitude of 42 degrees the intersection would be parallel to an element of the cone and hence a parabola; and from 42 degrees to 0 degrees altitude, the form would be a hyperbola the figure seen and measured by Mr. Heath. These

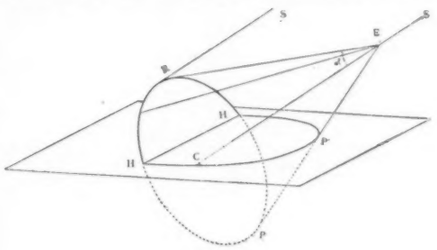


Fig. 2

ground-bows are probably mostly seen in the early morning hours before the dew has evaporated, yet are not restricted in time as is the rainbow, which has a limit for the altitude of the sun. A phenomenon which, as far as known to the writer, has never been seen, is a rainbow and a ground-bow at the same time. It certainly would be a pretty sight. From one's feet the arms of the hyperbola—for a hyperbola it would be—would run along the ground and meet the feet of the arc of the rainbow spanning the sky, as shown diagramatically in Fig. 2.

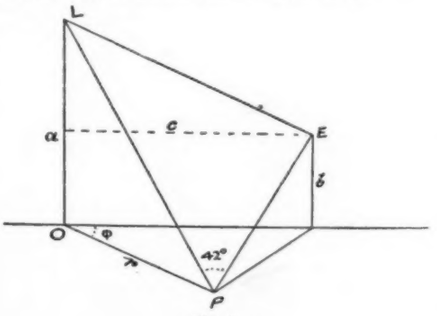


Fig. 3

In Fig. 2, *H R H* represents a rainbow with the sun at altitude of 30 degrees. *H H* represents the horizon and *H R P H* the circular base of the cone. *H P' H* is the intersection of the cone by the ground and hence represents the ground-bow when the ground is covered with water globules.

In conclusion reference may be made to a somewhat rare phenomenon of a ground-bow seen at night due to the same law of refraction and reflection but where the source of light is an electric street lamp and the ground covered with minute drops of water. In the case referred to by Dr. C. G. Knott, in the *Proceedings* of the Royal Society of Edinburg, in December, 1898, the minute spheres of water were due to the settling of fog in quiescent air. Here we have not parallel rays, as with the sun, and the form of the bow is not that of a conic section. From the adjoining Fig. 3 we readily deduce the equation of the curve of this ground-bow. *L* is the position of the light, *E* that of the eye, and *P* any point on the curve on the horizontal ground. *O* is the origin, and the measurements are as indicated.

Expressing this in terms of the measurements we obtain

$$(r^2 - r\,c\cos\phi + a\,b)^2 =$$
$$\cos^2 42^\circ\,(r^2 + a^2)\;(b^2 + r^2 + c^2 - 2\,r\,c\cos\phi),$$

an equation of the fourth degree. When the eye is directly under the light the equation becomes that of a circle, and in general *r* will have two values, *i. e.*, there will be two circular ground-bows.

The question of horizontal bows has recently been treated by Kokichi Otobe, in the U. S. *Monthly Weather Review.*

Vocational Education in England

AT THE Conference of Educational Associations on January 3, 1917, Mr. J. C. Maxwell Garnett, M. A., Principal of the Municipal School of Technology, Manchester, lectured on "The Vocational Outlook in Education." He opened his lecture with the remark that "Our education prepares most children for vacations and not vocations," and this provided his chief theme. His experience at the Manchester School of Techonology forced him to the conclusion that the education of the child in a general way, hitherto adopted, was unsatisfactory; for, as he said, "if you want a man to be a rower, you would teach him to row"; and, similarly, if you want to produce a good business man, you must teach him something that he can find useful in his career. The great point at issue is what is the real aim of education, a point on which there is no agreement as yet. In his opinion, education is not an end in itself, and is only useful in so far as it fits the pupil for life and the furtherance of the good of his country. The energies of the greater part of the people of Great Britain after the war will be devoted to recouping its industrial losses, and to this end, those minds found suitable to such labor should be specially trained. It should be the duty of the teachers to find the chief bent of their pupils, what he called their "single wide interest," which should be encouraged and cultivated on special lines, but he denied the accusation that such a system would be over-specialization. Thus every unit of the community would be an effective unit. He laid down the proposition that no man ought merely to live to work, but that he should be trained in the work which he himself preferred to all others, so that his work should become his pleasure, apart from any pecuniary consideration. He recognized the fact that there existed some very mechanical labor which could fascinate no one; but this should be reduced to seven hours a day, thus leaving the workman time for other and more congenial employment. Dealing with the universities, he maintained that they should throw their doors open to all, provided the would-be students showed themselves fitted for such education, and not insist that the secondary schools should be the sole channel of entry into university life; and further, that if a boy was compelled to earn his living after leaving school, this should not debar him from obtaining university instruction in later years. A useful hint was given in the discussion that followed by a headmaster of an elementary school. He said he was often consulted as to a suitable career for his pupils, but the method of education was such that the pupil had no free time in which to develop his own interests, and in consequence he (the master) knew nothing of his pupils except their success or failure in examinations.—*Science Progress.*

Substitutes for Coal for Gas-Making

SAWDUST and wood are, according to the *Journal des Usines à Gaz*, to be used in Switzerland and France as substitutes for coal for gas-making. In Geneva, 10 per cent of sawdust is added to the coal in vertical bulb retorts; as an alternative, logs of wood, 3 feet in length, are placed in the retorts, which then contain only charges of 260 pounds instead of 1,240 pounds of coal. Wood and coal are worked alternately on two benches, and the gases not being kept separate, the resulting tars are not acid. At La Chaux de Fonds, in the Jura, 375 pounds of sawdust are mixed with 66 pounds of coal in horizontal retorts which took 990 pounds of coal. In Neuchâtel the coal is mixed with 28 per cent of wood. In Arcachon, in the Gironde district, heath roots are carbonized in 2½ hours; the charcoal is said to be superior to pine charcoal, and the gas satisfactory. A cargo of condemned flour was carbonized at Royan, giving a very good coke free of ash. The acid products of wood distillation have given some trouble and corrosion, which the alternate working of charges of coal and of wood diminishes.

Effective Methods of Fly Control*

A Review of the Factors That Underlie the Problem

By Thomas J. Headlee, Ph. D., Prof. of Entomology in Rutgers College, Entomologist of the New Jersey Agricultural Experiment Stations, and State Entomologist

"SWAT the fly" has been a slogan of anti-fly workers for about ten years. The publicity campaign begun at that time and carried on ever since has been so complete that the danger of the housefly and its associates as carriers of infection is well understood in even the humblest of the English reading homes of our country. Without doubt this campaign has promoted the anti-fly effort to such a degree as to pretty completely exclude the insect from the homes of the better-to-do and to limit correspondingly the amount of harm done by it as a carrier of disease. Unfortunately, the expenditures incident to screening are sufficiently high to prevent the poor and the relatively ignorant from denying it access to their homes.

In spite of various local efforts in various parts of this and other countries to bring the fly and its associates under control it has rarely been possible to reduce them to such a point that specimens are really rare. This being the case, if we would improve on what has been accomplished elsewhere, it is necessary to review our knowledge of the factors that underlie the problem and to bring it up to date.

COMPOSITION OF THE FLY FAUNA

Perhaps, the first step in this direction is an inquiry into the composition of the fly fauna of typical localities. Unfortunately, the data bearing on this point are limited and are concerned with a location on a farm which lies in the edge of a city of about 35,000 people. The horse barn, the pig plant and the poultry plant are all located on the Rutgers College Farm in the edge of the city. The flies were caught in traps baited with milk and bran which is known to attract practically all species that visit human food and human dwellings.

From the above tables it appears that at the beginning of the season the housefly is conspicuous by its absence. In 1913 it was the beginning of June before that species reached 50 per cent. of the fauna, and in 1914 it was only in the latter half of June that it became abundant. From the middle of June in 1913 and the first of July in 1914 it became the dominate species, forming 90 per cent. or more of the fauna, and remained so until the end of the season.

The little housefly and the garbage flies were dominate at the beginning of the season, were quite outnumbered in the hot weather and again rose in importance as the season drew to a close.

It is thus shown that 90 per cent. or more of our fly trouble is due to the species variously known as the housefly, the typhoid fly and *Musca domestica*.

SOURCES OF FLIES

Perhaps, the next point of large importance is an inquiry into the source of flies, particularly of the housefly.

Hewitt[1] submits a list of substances in which breeding has been found and groups them under the general headings of "Excrementous substances," "Vegetable substances," "Animal substances" and "Miscellaneous substances."

Among the excrementous substances are horse manure, human excrement, fowl excrement, cow manure, pig manure and rabbit manure. Among the vegetable substances are spent-hops, decaying grain, cooked peas, rotten watermelon, rotten musk or other melons, rotten cucumber, rotten carrots, rotten cabbage, rotten potatoes and pulings, barley malt, excreta-soiled straw, bread, cake, bread and milk, rotten apricots, rotten bananas, rotten cherries, rotten plums, rotten peaches and boiled rice. Among the animal substances are rotten meat, carrion, cattle paunch contents, rotten fowl feathers, old broth and boiled eggs. Among the miscellaneous fly breeding materials are kitchen refuse, fermenting substances in ash pits, saw dust and excrementous refuse, garbage pile drainage, cesspool, snuff, expectoration with earth, excreta soiled paper or rags, ensilage and rubber.

It thus appears that the housefly may breed in almost any kind of organic matter when the conditions are right.

Richardson[2] has shown that the female housefly when ready to oviposit is decidedly attracted to and will lay her eggs upon substances from which ammonia is being evolved. The maggots, which hatch from the eggs, require a certain degree of moisture and warm temperature. That degree of moisture which is characterized by a peculiarly slippery condition seems best and a temperature ranging from 70 degrees F. to 95 degrees F. is required. Submersion of the food in water or thoroughly drying it out will destroy the larvae. At 50 degrees F. or below little or no development takes place and 104 degrees F. will, if continued, kill the maggots.

Horse manure because of the rapid and vigorous evolution of ammonia is very attractive to the fly as a place to lay her eggs and because of the degrees of moisture and temperature usually developed is a prime medium for the development of the maggots.

When cow manure is mixed with a considerable quantity of shavings, as is the custom in many dairy plants, it becomes almost as active a breeder as horse dung.

Considering its almost universal distribution and the exceptionally favorable breeding conditions which it produces, horse manure is without doubt the principal source of houseflies both in the urban and the rural districts.

It has been shown by Faichne[3] in India that 4,000 flies may come from 1-6 of a cubic foot of soil from a privy and 500 from a single dropping of human excreta. It has been shown by Herms in California that 15 pounds of horse manure, or the average amount produced by one horse in one day, may breed as many as 10,282 maggots. Howard states that 160 maggots and 146 puparia were found in a quarter of a pound of horse manure in a pile in Washington, D. C.

It is a common impression and one fully borne out by the writer's experience that 90 per cent. or more of the housefly fauna comes from horse manure.

MIGRATION OF FLIES

Granting that the housefly is fully 95 per cent. of the fly pest and that 90 per cent. of the houseflies come from horse manure, the next important step is to determine the distance to which it will migrate. Many studies bearing on this point have been made. Hewitt[4] in the course of his studies at Ottawa, Canada, has shown that an extreme migration of 700 yards or a little less than ½ a mile may take place under city conditions. Parker[5] in his studies in Montana has shown that in extreme cases the migration may reach 3,500 yards or almost 2 miles from the point of breeding.

The factors which lead the fly to migrate are probably odors from feeding and breeding grounds. High winds tend to compel the fly to seek shelter and thus to reduce migration. Gentle winds, on the other hand, tend to disseminate the odors which attract the flies and do not interfere with their movements, and thus favor extensive migration. Low temperatures by re-

Table to Show Seasonal Appearance of Flies in Different Typical Locations.

DATE.	DAIRY BARN.						HORSE BARN.					PIG PLANT.						POULTRY PLANT.				
	Percentage of typhoid flies.	Percentage of little house flies.	Percentage of biting house flies.	Percentage of stable flies.	Percentage of garbage flies.	Percentage of horn flies.	Percentage of typhoid flies.	Percentage of little house flies.	Percentage of biting house flies.	Percentage of stable flies.	Percentage of garbage flies.	Percentage of typhoid flies.	Percentage of little house flies.	Percentage of biting house flies.	Percentage of stable flies.	Percentage of garbage flies.	Percentage of dung flies.	Percentage of typhoid flies.	Percentage of little house flies.	Percentage of biting house flies.	Percentage of stable flies.	Percentage of garbage flies.
4-26-'13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	80	...	...	20
5- 3-'13	...	50	...	...	50	...	10	75	5	...	10	10	50	...	...	30	10	...	75	...	...	25
5-10-'13	...	50	...	...	50	...	10	70	10	...	10	10	50	...	...	30	10	10	60	5	...	25
5-17-'13	40	25	10	...	25	...	10	70	10	...	10	20	45	...	...	30	5	10	60	5	...	25
5-24-'13	50	...	10	...	30	10	20	60	10	...	10	35	35	...	...	30	...	20	50	5	...	25
5-28-'13	60	...	5	...	20	15	30	50	10	...	10	45	30	...	...	25	...	30	40	5	...	25
6- 4-'13	75	...	2	...	10	13	40	40	10	...	10	55	25	...	...	20	...	45	20	10	...	25
6-11-'13	90	...	1	...	...	9	50	30	10	...	10	60	20	...	...	20	...	45	20	10	...	25
6- 9-'13	95	...	...	...	...	5	60	20	10	...	10	70	15	...	...	15	...	45	20	10	...	25
6-26-'13	99	...	...	...	...	1	70	15	5	..	10	80	5	...	...	15	...	80	10	...	...	10
7- 5-'13	90	...	...	...	...	10	80	10	5	...	5	85	5	...	...	10	...	85	5	...	...	10
7-12-'13	90	...	...	...	...	10	98	...	1	...	1	90	...	...	...	10	...	98	1	...	...	1
7-19-'13	85	...	2	...	...	13	98	...	1	...	1	98	...	...	...	2	...	95	...	...	...	5
7-26-'13	85	...	2	...	...	13	98	...	1	...	1	98	...	...	...	2	...	90	...	...	...	10
8- 2-'13	85	...	2	...	...	13	98	...	1	...	1	95	...	...	...	5	...	90	...	...	...	10
8- 9-'13	85	...	2	...	...	13	98	...	1	...	1	90	...	...	...	10	...	90	...	...	...	10
8-16-'13	85	...	2	...	...	13	98	...	1	...	1	90	...	...	...	10	...	90	...	...	...	10
8-23-'13	80	...	2	...	...	18	98	...	1	...	1	95	...	...	...	5	...	90	...	...	...	10
8-30-'13	75	...	7	...	...	18	98	...	1	...	1	95	...	...	...	5	...	90	...	...	...	10
9- 6-'13	75	...	7	...	...	18	98	...	1	...	1	95	...	...	...	5	...	90	...	...	...	10
9-13-'13	75	...	7	...	...	18	98	...	1	...	1	95	...	...	...	5	...	90	...	...	...	10

Table Showing Comparative Abundance of House Flies at College Farm in 1914.

H. F.—House Flies. O. F.—Other Flies

DATE 1914.	Pig Barn.		Poultry Plant Brooder House.		Horse Barn.		Horse Barn Manure Pit.		Cow Barn.		Cow Barn Manure Pit.		Calf Barn.	
	% H. F.	% O. F.	% H. F.	% O. F.	% H. F.	% O. F.	% H. F.	% O. F.	% H. F.	% O. F.	% H. F.	% O. F.	% H. F.	% O. F.
4/24	....	100	....	100	....	100	....	100	....	100	...	100	....	100
5/8	....	100	....	100	....	100	....	100	....	100	...	100	...	100
5/9	....	....	....	....	....	....	....	....	....	....	...	....	...	....
5/13	....	100	....	100	....	100	....	100	.05	99.95	...	100	...	100
5/19	12.5	87.5	7	93	....	....	....	100	5	95	...	100	...	....
5/25	22	78	....	100	1	99	11	89	....	....	...	....	...	....
6/2	7	93	....	93	5	95	....	....	....	....	...	....	...	....
6/3	....	....	....	....	....	....	....	....	16	84	4	96	30	70
6/9	20	80	10	90	10	90	....	....	20	80	...	....	30	70
6/20	....	....	....	....	....	....	....	....	85	15	...	....	90	10
6/30	....	....	....	....	....	....	....	....	85	15	1	99	....	....
7/2	95	5	....	....	70	30	....	....	....	....	...	....	....	....
7/10	90	10	98	2	....	....	1	99	99	1	...	100	....	....
7/18	98	2	98	2	....	....	....	....	....	....	5	95	99	1
7/24	....	....	....	....	....	....	....	....	60	40	...	....	....	....
7/27	99	1	96	4	....	....	60	40	60	40	...	....	99.9	1
7/29	80	20	....	....	....	....	50	50	....	....	...	....	....	....
8/1	99	1	85	15	....	....	66	34	....	....	...	....	99.9	1
8/4	99	1	....	....	....	....	....	....	....	....	...	....	....	....
8/7	99	1	99	1	....	....	95	5	....	....	...	100	....	....
8/10	....	....	....	....	....	....	....	....	3	97	...	....	....	....
8/21	99	1	96	4	....	....	95	5	....	....	...	....	....	....
8/25	....	....	....	....	....	....	....	....	10	90	...	....	99	1
9/1	99	1	....	....	....	....	95	5	....	....	...	....	....	....
9/14	99	1	....	....	90	10	....	....	....	....	...	....	....	....
9/16	....	....	....	....	....	....	....	....	15	85	...	....	95	5
9/22	99	1	70	30	....	....	....	....	....	....	...	....	....	....
9/28	....	....	....	....	....	....	70	30	25	75	...	....	90	10
9/29	99	1	67	33	....	....	....	....	....	....	...	....	....	....
10/5	90	10	53	47	....	....	75	25	....	....	...	....	....	....
10/20	80	20	....	....	40	60	....	....	30	70	...	....	90	10

*A paper read before the N. J. Sanitary Association.

[1]Hewitt, C. Gordon, "The House-Fly," Cambridge Zoological Series, p. 94, 1914.

[2]Richardson, Charles H., Bul. 292, New Jersey Agricultural Experiment Stations, 1916.

[3]Faichne, N., "Fly-borne Enteric Fever; the Source of Infection," Journ. Ray. Med. Corps, Vol. 13, pp. 580-584, 1909.

[4]Hewitt, C. Gordon, "The House-Fly," page 72, 1914.

[5]Parker, R. R., Journ. of Ec. Ent., pp. 325-253, 1916.

ducing the fly's activity would tend to limit migration while high temperatures would favor distribution for the opposite reason. Rain causes the flies to seek shelter and therefore tends to restrict migration. There is some reason to think that high hills interfere with the progress of the insect and tend to restrict migration. Rivers, even when broad, seem to have little effect on distribution.

According to Parker, given sufficient time, flies will become rather evenly distributed over a large area and even in a city of considerable size every person allowing flies to breed on his premises is maintaining a nuisance which directly affects every other individual residing in the city. In two weeks under favorable conditions flies will distribute themselves over an area 3 miles in diameter, providing it is built up. Distances of over a mile have been covered within five days.

Nevertheless, we know very definitely that a section of a city from which fly attracting odors have been practically eliminated has very few flies, although other parts of the same city where those odors are rampant may be swarming with them.

It thus appears that the organization undertaking fly control must deal with an insect that is prevalent throughout the summer, breeds in all sorts of rotting organic matter, especially in horse dung, and which may distribute itself over an area of at least four miles in diameter.

METHODS OF CONTROL

Three methods of attacking the problem have been tried—destroying the adults, eliminating the breeding places and employing a combination of the two.

TRAPS AND POISONS

Adult flies may be destroyed by traps and by poisons. Some enthusiasts have maintained that by traps alone the fly pest can be eliminated. Just recently a concern at Paducah, Ky., has been bedevilling the writer to test out a fly trap which it has placed on the market. This concern sends a testimonial from the mayor of that city which reads as follows:

"Gentlemen:

"About the 25th of May we purchased and installed in our city two hundred —— fly traps and I wish to state that we have practically eliminated the fly from our city by use of these traps.

"I consider their purchase one of the best investments this city has.

"Very truly yours."

In 1913 after extensive use of fly traps of various types in the city of New Brunswick and on the College Farm the writer said: "The best that can be said for traps is that they are an adjunct to fly control. The advocacy of the use of traps as a sufficient measure of fly control is pure folly, if the experience of the past summer (1913) counts for anything." Thus far he has seen no reason to change his opinion.

In some instances poisoned baits have been used on a large scale against adult flies. In 1913 Berlese reported on two years of experiments against houseflies at S. Vincenzo (Pisa), Italy. The first year he sprayed plants in the gardens and orchards near houses, manure piles and other places where flies congregated. He used a mixture composed of 10 parts treacle, 2 parts of arsenite of potash or soda, and 100 parts of water, and made the applications every 10 days. After every rain the spraying was repeated. The second year he suspended small bunches of straw, which had been dipped in a mixture of honey (1 part), treacle (1 part), sodium arsenite (⅛ part) and water (10 parts), under conical zinc covers. The baits were hung about houses on or near porches and verandas. Berlese states that he succeeded in eliminating the fly pest during each of the two years and believes that the method might be successfully used in large cities.

In South Africa, Malley used a solution composed of 1 pound of sodium arsenite, 2 gallons of cheap molasses and 10 gallons of water. He applied this material with a spray pump to branches of trees, piles of refuse and in fact anything which offered a smooth and comparatively non-absorptive surface in places where flies gathered. The resultant control is said to have been excellent.

ELIMINATION OF BREEDING PLACES

Fly control through the elimination of its breeding places has met with greater success than any other method. Many campaigns have been carried on in various parts of this and other countries and in some cases pretty good results have been obtained. In 1913 the writer summed up the results of fly control in the city of New Brunswick, on the College Farm and on a dairy farm as follows:

New Brunswick.—"For a period of eight weeks the city maintained a clean-up campaign, devoting a week to each ward and two weeks to the especially bad places. During this time the owners and tenants had merely to gather the rubbish and pile it on the street edge, when the street department wagons carted it away. This clean-up campaign eliminated an enormous number of fly-breeding places. With comparatively few exceptions, the health inspectors completely failed to get such open privies as could not be eliminated treated regularly or frequently with a larvicide. The health inspectors were unable to get anything like all of the stables treated according to plan. Three weeks delay following May 14th brought out many flies—enough for a considerable number to appear on one of the principal streets of the city. From that date until August 1st there was no appreciable increase in numbers, although the season was favorable. During this period the prolific breeding stables were closely watched, and comparatively few flies got out. As the 15th of August approached the flies became much more abundant and continued to increase until the middle of September. This period of increase coincided with a decrease in attention to the bad breeding stables.

College Farm.—Before the work could get fully started the flies made their appearance in considerable numbers on the farm and about the buildings. Soon they fell off, and continued in such small numbers that on August 5th, when 1,500 farmers visited and spent the day at the College Farm, although a food-vending stand and family lunch baskets were much in evidence, scarcely a fly was to be seen.

Dairy Farm.—Before the fly work began the flies had become very abundant. A sample of milk secured at this time showed a bacterial count of 700,000 per cu. cm. On August 13th after the fly work was well under way a sample of milk showed 90,000 per cu. cm.

The elimination of fly-breeding places involves the removal of fly-breeding substances, killing of the maggots with larvicide or destruction of adults or larvae with traps.

The first type of removal consists in the gathering up of all rubbish and its removal to a place where it can be burned, or dried out. In the city this can best be accomplished through a clean-up campaign and in the country through raking up the rubbish and burning it. The second type of removal consists of the bi-weekly removal of all constantly produced, fly-breeding substances, principally horse manure. In the city this can best be done through a regular removal service while in the country it can best be done by throwing the manure from the stables into the manure spreader. The third type of removal consists in the abandonment of open privies and the connection of the toilet with the sewer by the enforcement of law. This procedure can, of course, be employed only where sewers exist.

Killing of the maggots with a larvicide involves a number of problems. The material employed must be effective, cheap, easy to apply, non-injurious to the fertilizing value of manure and preferably non-poisonous to the higher animals and man. An immense number of substances have been tried, mostly, with reference to their power to kill maggots. Many have proven able to destroy larvae but few have been found that at all closely approach all the conditions mentioned. In the seasons of 1913, 1914 and 1915 a long series of inorganic and organic compounds was studied by the Bureau of Entomology of the United States Department of Agriculture and only two substances that approximately filled the requirements were found. They were *borax* and *hellebore*. The former answered all requirements except that of non-injury to manure. It was found that when borax-treated manure was used in large quantities—say, more than 15 tons to the acre—the plants grown upon the soil were injured. Hellebore proved to be entirely free from that objection but is rather high priced. Certain fertilizer mixtures have been shown to be promising. Such a mixture composed of ½ of a pound of calcium cyanamid and ½ a pound of acid phosphate per bushel of manure destroys maggots and increases its fertilizing powers. With 8-cent borax at the rate of 1 pound to 10 gallons of water in 8 bushels of manure the cost for material is ½ a cent a bushel. With 17-cent hellebore at the rate of ½ pound to 10 gallons of water in 8 bushels of manure the cost of material is 1 cent a bushel. With the calcium cyanamid and acid phosphate mixture the cost is 1.8 cents per bushel with of course quite a material increase in fertilizing value.

Manure may be thrown in a tight receptacle covered with a fly trap in which the emerging flies are caught and left to die. Manure may be thrown upon a raised slat platform under which a pool of water is maintained. If the mass is kept wet by pumping water over it at intervals the maggots will crawl out as they mature, fall into the water and be drowned. The usual arrangement is to pump the water from the underlying pool over the manure mass as needed to keep it wet.

It would seem that the utilization of both types of attack in a single anti-fly campaign needs no discussion.

STEPS IN AN ANTI-FLY CAMPAIGN

Assuming that in planning a modern anti-fly campaign the problem should be attacked from as nearly every quarter as possible, the first step is a careful survey of the protected area and its environment for possible fly-breeding places, followed by the creation of a careful record, drafting a graphic chart showing their location, and the preparation of plans and estimates whereby the breeding places may be eliminated. Without doubt this plan should include an extended clean-up campaign, the enforcement of ordinances eliminating the open privy and forcing connection of toilet with sewer, the adoption of an ordinance making it a punishable offense to maintain fly-breeding on the premises, the employment of sufficient men to examine all permanent breeding spots twice each week, and lastly the employment of a competent person to oversee the work and maintain its efficiency.

The second step is the carrying out of a good publicity campaign, making the people who are to be protected so thoroughly familiar with the need and nature of the work that their full cooperation may be had and the necessary funds obtained.

The third step is the creation of the organization followed by the maintenance of its efficiency.

The fourth step is to render the results so satisfactory that fly control will become a permanent feature of sanitary work.

Emphasis should be placed on the elimination of breeding but poison bait should be fully used when the flies are abundant, especially near difficult breeding places.

Fly traps should be placed at regular intervals throughout the protected area. They should be kept well baited with loaf sugar. Each week they should be emptied and the contents measured. These records will show the nature of the distribution and consequently where the most concentrated work is needed. They will also indicate invasions should any occur.

This year a fly campaign on these lines was carried out in the Borough of Beach Haven, which is located on Long Beach, a narrow strip of sand lying across the bay from Tuckerton and separating the bay from the open water of the Atlantic Ocean. Beach Haven is rather well isolated, being fully five miles from the mainland and having very little settlement either immediately north or south of it. Although the breeding was not as well taken care of as could be desired, the flies were scarce throughout the summer.

From his experience of the last four years in fly control, the writer is firmly convinced that the house fly can be rendered rare in our towns and cities but that a special organization, the duty of which is to do this work, must be created in each place before that end can be reached.

Oil For Air Compressors

In the course of a paper on the "Chemistry and Examination of Lubricating Oils" read before the Diesel Engine Users Association, Mr. Elliott A. Evans made some remarks on the quality of oil required for use in air-compressors.

He said that the Pennsylvanian oils are the only ones moderately stable when subjected to the action of highly compressed air, and then only at moderate temperatures. At elevated temperatures the oil cracks, giving rise to lighter oils which in their turn crack into still lighter oils. During the cracking carbon is deposited, and some extremely unstable hydrocarbons, probably of the olefine series, are formed which decompose with explosive violence. It is quite conceivable that the explosion in an air-compressor at Smithfield occurred through the production of these unstable bodies, and that the vapor of the light oils was exploded by their detonation. That the explosion was caused by the ignition of oil fog may be a very convenient working hypothesis, but it is a little difficult to understand how ignition was effected.—*London Times Engineering Supplement.*

The Evolution of the Human Face

Chief Stages in Its Development from the Lowest Forms of Life to Man*

By William K. Gregory

I SUPPOSE if you have talked to people about evolution they have said: "Well, if monkey-like animals evolved into men at one time, why did not all monkeys evolve into men, and why are there any monkeys alive at the present time?" They ask me to explain it, and they regard it as an insurmountable objection to the theory that man has evolved from lower mammals. Now I do not know why all the monkey-like animals did not evolve into men instead of changing only a little and remaining monkeys, but I do know that evolution, besides proceeding in different directions, also proceeds at different rates at different times. I know that just as there are many very advanced and progressive races, such as the horse and the humming bird and the whale, which have undergone a very great modification during the vast period known as the Age of Mammals, so there are also many conservative and backward races, such as the tapir and the opossum and the tuatara, which have undergone very little modification during the same period. These backward and primitive races are of the greatest use to us in deciphering the evolutionary history of past ages. They are living relics, or living fossils. A great many such relics are living to-day. That is what furnishes the material for comparative anatomy. It is by the dissection and study of these extant fossils and by comparing them one with the other, that we can trace out the stages by which structures have changed slowly, one into the other, and by which types have changed, one into the other. Now the monkeys and apes are relics of the middle periods of the Age of Mammals, and we know from the fossil remains that they have changed but little during that period. A possible reason is that most of them have continued to live in the forests and have therefore kept their primitive tree-living habits unchanged, while only a few, such as the baboons and the early predecessors of man, have left the forests and taken up wholly new habits on the plains, so that under the pressure of new conditions of life they have changed profoundly. But although other factors may be involved in the final answer to the question why have all the monkeys not evolved into men, it is true that by saving these relics of long past ages Nature has provided us with materials for elucidating the evolutionary history of human structures.

Skulls of human infant (above) and young chimpanzee (below)

The elements of the human skull are homologous with those of the ape, the differences between the two arising from the great expansion of the brain and the deepening and shortening of the face in man.

In considering the evolution of the human face, we gain a better perspective by beginning with the lowest animals and working upward. It seems that in the course of evolution the oldest part of the face is the mouth. The primary business of the face, in fact, is to direct the mouth toward the food. Some of the lowest, one-celled animals show this first essential of a face, which leads into a cavity that serves as a stomach, and among the anemones and corals and their relatives we find a well developed mouth, surrounded by sensory organs (tentacles).

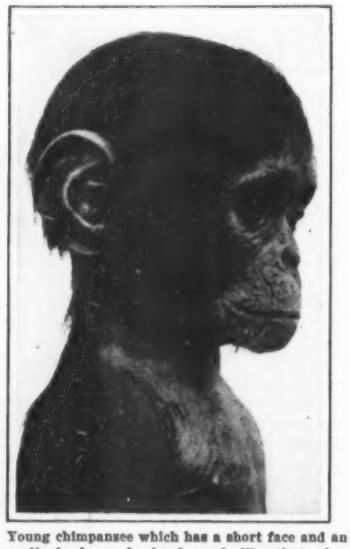
The flatworms show the presence of eyes in a very primitive condition, another structure which goes to make up the face of higher types; that is, there is a concentration of nervous tissue sensitive to light at one end of the animal, which is shaped so as to progress in a forward direction, with the beginnings of a head and of a tail. In *Peripatus*, a wormlike animal, there are little tubercles on the skin equipped with hooks which help to pull the food into the mouth, and a number of paired limblike appendages on either side behind the mouth. These appendages become of importance in insects and crustaceans, those at the front end of the series becoming modified into sensory structures and also in many cases serving to get food and convey it to the mouth.

In some insects the tough skin which covers these appendages has been modified into a sawlike edge, and here we have a suggestion of jaws, which are the next great element to be added to the face.

Finally we see in many ordinary insects, such as a grasshopper, a rather high type of face for this grade of animal. It is completely armored on the surface with a tough skin. In many lower types of vertebrates also the head is armor-plated like the rest of the body so that the head is protected by a helmet and the body by a cuirass. Insects naturally evolved a kind of face with a number of the characteristics of the face of higher animals, because some sort of face involving a mouth and jaws and paired sense organs is necessary at the front end of any animal that goes after its food in a fore-and-aft direction.

The very ancient fishlike vertebrates of the Silurian and Devonian ages also had a head covered with a bony skin which formed a cuirass and a helmet, and in some (*Bothriolepis*, etc.) the eyes were on top of this helmet

*Lecture delivered before the Linnean Society of New York. Republished from *The American Museum Journal*, issued by the American Museum of Natural History, New York.



Young chimpansee which has a short face and an exceedingly large forehead much like that of a young child. Photographed by Herbert Lang on the American Museum Expedition to the Belgian Congo.

The photograph shows the tense lips of a trained chimpanzee in the act of threading a needle. The action of the muscles of the human face is co-ordinated (especially in the child) with that of various other muscles of the body, and the same is noticeable in apes, which use the facial muscles much as we do. Courtesy of Professor W. T. Shepherd, of Washington, D. C.

The facial muscles are supplied by branches of the seventh or facial nerve, which issues from the skull behind and below the ear. It is believed that the throat muscle in remote ancestors of mammals spreads upward between the bone and the skin, carrying the seventh nerve with it, and that as the muscle branched, the nerve also branched again and again, producing the highly mobile sensitive face of man. From Cunningham's *Anatomy*.

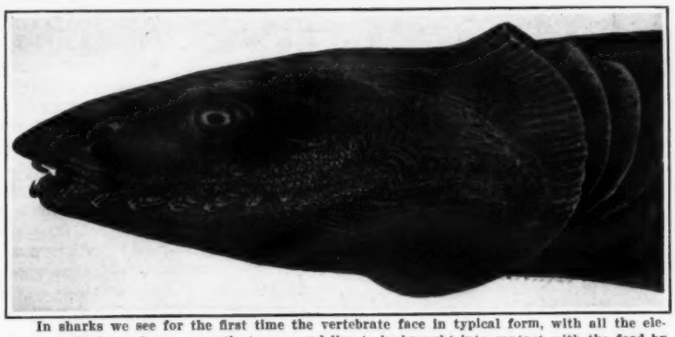
much as they are in the grasshopper. The jaw parts of this vertebrate are likewise made up of bony plates on the surface, and no doubt the muscles pulled these jawlike plates back and forth much as they do in the insects. I do not mean that this fishlike animal with its grasshopper-like face has been evolved from the insect plan of organization; I am merely suggesting that general resemblances of this sort are frequently evolved in widely different groups in response to similar functional needs.

It is not until we reach the sharks, which are the most normal and typical of the fishlike vertebrates, that we see the vertebrate face in its typical form and that we see all the elements which are characteristic of the face of mammals. Even the familiar landmarks of the human face are all present. We have the nostrils, which are only indefinitely foreshadowed in earlier types; we have the eyes, the mouth, the tongue, and the lips. But in the shark the whole face is covered with a tough skin.

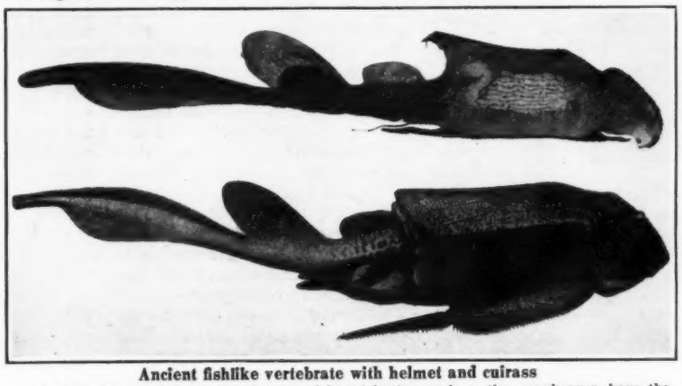
In certain sharks (*Chlamydoselachus*) we see a suggestion as to how the teeth were formed in higher vertebrates. The tough skin, covering the head and body, is everywhere thickly studded with minute teeth, or denticles, the whole forming the "shagreen" of commerce. Now the teeth in the sharks' mouth are nothing but enlarged shagreen denticles. At the sides of the mouth the denticles gradually become larger and the skin that bears them becomes drawn over the margins and on to the inner side of the jaws. I need hardly say that the evolution of the teeth of vertebrates has had a great influence upon the evolution of the face.

In the shark the face is very distinctly the directing part of the animal, at the front end of the backbone. We may say that all the elaborate locomotive organs (the backbone, the fins and the muscles which move them) exist chiefly for the purpose of bringing the mouth into contact with the food, and that the higher elements of the face, namely the eyes and the nose, exist for the purpose of directing the locomotive apparatus toward the prey. In order to consume the food and transform its potential energy into action, the shark must of course have oxygen, which among fishes is extracted by the blood from the water surrounding the gills. These gills are supported by cartilaginous arches which are of the greatest importance in the later evolution of the face, since there is good evidence tending to show that the upper and lower halves of one of these gill archies actually gave rise to the upper and lower jaws of the sharks, which are equivalent to the cartilaginous core of the upper and lower jaws of all the vertebrates above the sharks.

The fishes called "ganoids," of many different varieties, show a shiny surface armature covering the face, as also the body, recalling the insects with their hard outer shell. But the noteworthy thing about this ganoid sort of face is that the hard covering of the face and jaws has a bony substratum which completely invests the primary, underlying brain case and the primary or gill-arch jaws. This bony skin even extends inward along the roof of the mouth, forming the primitive hard palate, and along the inner as well as the outer side of the primary lower jaw, forming the sheathing bones of the jaw, which are typical of fishes and higher vertebrates. In this early stage of vertebrate evolution this bony mask lies fully on the inner and outer surfaces, but in the later evolutionary stages of all classes of vertebrates, these sheathing bones gradually sink below the surface, in proportion as a new layer of skin is generated on *their* surfaces, and as this new surface layer becomes thicker the original sheathing bones finally come to be buried deeply under the skin and often tightly appressed to the still deeper primary brain case and primary jaws.

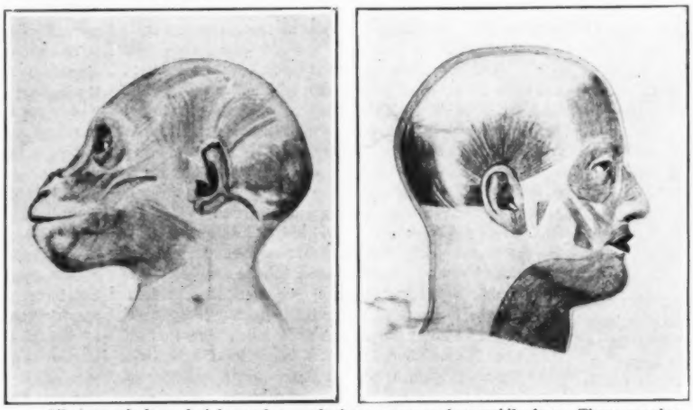


In sharks we see for the first time the vertebrate face in typical form, with all the elements of the face of man—mouth, tongue and lips to be brought into contact with the food by the locomotive organs, and nostrils and eyes to direct the locomotive organs. In the frilled shark figured we see a suggestion of how teeth were formed in the higher vertebrates.



Ancient fishlike vertebrate with helmet and cuirass

Just as many highly developed types of invertebrates, such as the grasshopper, have the head completely armored with a tough skin, so in many low types of vertebrates the head as well as the body is armor-plated. Such was true of *Bothriolepis*, an extinct "fish" from the Devonian of Canada. The bony shell covering the head and thorax served the same purpose as the chitinous armor of insects.



All mammals have facial muscles, producing a more or less mobile face. These muscles are very highly developed in man. In a comparison of gorilla (young) and white man (adult), homologous groups are seen, such as the muscles surrounding the eyes, the nasal muscles, and the muscles that lift the lip. One of the greatest gaps in the evidence of the evolution of the face is that there has been found no intermediate type between the immobile nonmuscular face of reptiles and the mobile muscular face of mammals.

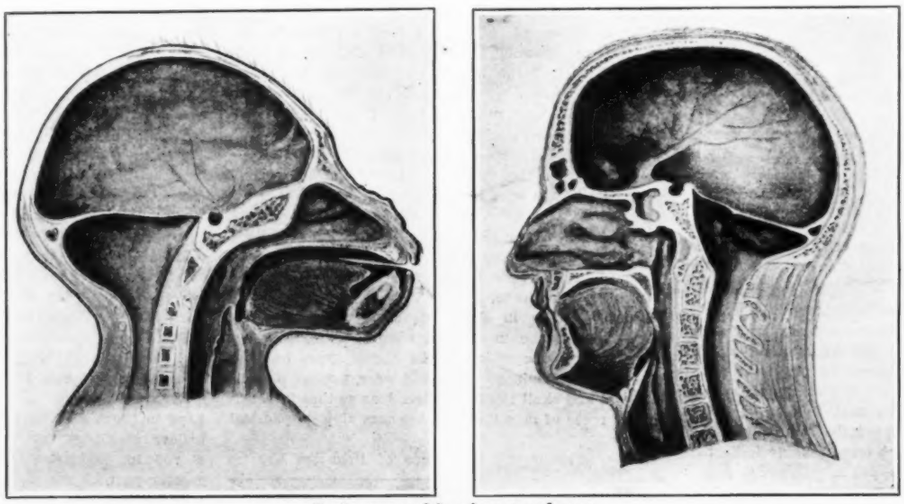
There have come down to us from the Age of Reptiles a great many fossil reptiles and amphibians which show this shell of bone still on the surface, or very near the surface. Even in the modern alligators and crocodiles and turtles the bony mask lies immediately below the tough skin.

An aggressive looking amphibian (*Cacops*) from the Permian of Texas has the general type of face which was destined to give rise by diverse modifications to the characteristic faces of reptiles, and indirectly to those of the higher types. It still has the mask of bone. It has a special interest, besides, since it possessed another very important structure in higher vertebrates—namely, an eardrum, which was doubtless stretched upon the bony rim behind the eye-sockets.

The Teju lizard represents a still higher grade of organization, the next step toward the mammals in one direction and toward the birds in another. It is an active, carnivorous animal, and its face is well protected by a mask of scaly skin. The bony mask is also still there, under the skin; but here is a point most important to remember, that if you took off the scaly skin of the face in this reptile, you would not find any facial muscles beneath the skin, such as are present in our own face. It is only on the under side of the jaws and throat that you would find a layer of muscles beneath the skin. In the absence of true facial muscles all reptiles are inferior in rank to the mammals, where facial muscles first appear. Birds have the immobile nonmuscular face of reptiles, further masked by a horny beak or bill; but the mammals have soft muscular lips and a muscular layer about the nose, eyes, forehead and ears.

One of the greatest gaps in the whole record of the evolution of the face consists in this, that in spite of the relative abundance of living relics that preserve successive stages in the evolution of the skull itself, there is no animal known which has an intermediate type of face between the immobile nonmuscular face of reptiles and the mobile muscular face of mammals. In spite of this, comparative anatomy furnishes fairly clear evidence as to the exact process by which the one did evolve into the other.

The facial muscles of a typical mammal, a lemur (*Propithecus*), for instance, correspond with the facial muscles of man. They include the platysma covering the throat, the orbicular muscle around the eye, the muscles of the nose, the muscles that lift the lip, the muscles that draw back the corners of the mouth, and the buccinator, which is of great use not only in blowing a trumpet, as its name suggests, but also in protruding the lips and in pushing the food about inside the mouth.



Brain case and face in ape and man

In the ape (young gorilla, at the left) the brain case is comparatively low, and the face is shallow; in man (adult white man, at the right) the brain case and the face are both very deep; the face has been retracted beneath the brain case.

All these various muscles of the face in man are innervated by branches of the seventh or facial nerve. The facial nerve comes out from behind the ear, and turns forward, one branch going to the platysma muscle on the surface of the throat and the other in numerous branches and sub-branches, like a vine and its divisions, passing forward to supply the muscles of the face. This fact gives the clue[1] to the origin of the facial muscles. In the remote ancestors of the mammals only the platysma and the immediately underlying sphincter colli muscles were present; it is highly probable that this sheet of nerve tissue gradually spread from the under side of the throat upward and forward along the sides of the face, by degrees creeping over the old bony mask and beneath the skin, carrying with it the seventh nerve, and dividing and subdividing into numerous branches and layers; at the same time the nerve branched and branched again, as nerves have frequently been known to do when muscles became subdivided. Several analogous cases of the spread of a muscle layer into a new region are known or suspected, as in the case of the mammalian diaphragm which is believed to have arisen in the neck region and to have migrated backward, dragging its nerves with it.

The facial muscles in man not only correspond with those in other mammals, but they also show special detailed resemblances when compared with the facial muscles of apes. Darwin and other investigators found that apes use these muscles much as we do, but with rather more emphasis than is usual in polite society. When a child first takes lessons on the piano, the teacher sometimes has to remind him or her that the piano should be played with the hands and not with the face—and sometimes it takes considerable repression on the part of the beginner to keep the facial muscles still, while striving to do anything with the hands that requires intense concentration and effort. A trained chimpanzee, trying very hard to thread a needle, has an intent expression and very tense lips, reminding us of the familiar human trait.

A gorilla in anger lifts the lips so as to expose the canine teeth and swells the muscles that run to the corners of the mouth so that they can be seen standing out on the side of the face. The arrangement of the wrinkles on the face in apes as well as in man seems to have a definite relation to the facial muscles, often forming across the pull of the underlying muscles. Perhaps the principal difference between the facial muscles of man and those of apes, apart from differences in relative size, is that in man the upper lip is full and protruded, while in the apes it is a thin "hard" lip, very muscular, but tightly drawn.

The human nose is hardly an inspiring subject from an anatomical point of view; internally it is decidedly degenerate, as compared with that of other mammals, and externally it has nothing very wonderful about it, like the nose of the elephant or those of various bats. The adult human nose, at least in the higher races, differs from that of apes chiefly in the following characters; the bridge of the nose is higher; the whole nasal cartilage is produced forward and downward, often ending below in a well-shaped tip; the nose is narrower at the base in proportion to its height, and the nostrils face downward rather than forward. Now, however important these differences may be from an æsthetic point of view, they are rather small from the standpoint of evolution, the more so since the nose of the human fœtus in its earlier and less differentiated stages is decidedly more ape-like than human. Even in babies the nose has by no means approached its adult human form. Among living apes the gorilla makes by far the nearest approach to the human condition in the shape of its nose, although the great width and the forward facing of the nostrils give it, according to human standards, a repulsive appearance.

In the face of the Australian black man we find some primitive gorilla-like characters along with others that are typically human. The nose is excessively wide at the base and the bridge between the eyes is very low, but the nostrils point downward and the tip of the nose is distinctly human.

A wonderfully well-studied restoration[2] of the extinct ape-man of Java (*Pithecanthropus*) shows a very wide nose, with the nostrils facing partly forward and partly downward, and with a deep depression above the nose, between the eyes; it also has a very thin upper lip and a partly everted lower lip; so that this mingling of human and apelike characters fully carries out the "missing link" idea which is so unmistakably indicated in the excessively low forehead and high brow ridges of this celebrated relic of a pre-human stage.

An interesting and grotesque caricature of certain human styles of nose is seen in two closely related genera of Asiatic monkeys, the "retroussé-nosed monkey" (*Rhinopithecus*) and the "proboscis monkey" (*Nasalis*). The former has the nose turned up at the tip and the nostrils facing forward, somewhat after the manner of a human fœtus, while the male proboscis monkey, as its name indicates, has its nose produced into a long downwardly directed tube with the nostrils facing downward. In the mandrill the inflated nose is made more striking to the eye by the addition of intensely blue and red pigments.

It has long been suspected that these variations of the nose in the higher Primates, including man, may have been brought about through sexual selection and that the form of nose has been determined by its decorative value, in accordance with the varied standards of beauty in the different races. Certain modern investigators, however, deny the potency of sexual selection to produce such results. Those who prefer to believe that differences in form are associated with differences in habit would perhaps favor the suggestion[3] that the downwardly pointing and hooded nostrils of man are primarily adapted to hunting habits and an upright gait, while the forwardly facing and open nostrils of the apes were adapted to frugivorous habits and a stooping gait. It may be also that the covered nostrils were better adapted for the rigorous, arid climate of the open plains, which according to my own view constituted the earliest habit of men after they had abandoned their ancestral home in the forests.

Passing to a consideration of the origin of the human eyes, we find in the Primates many intergradations from the condition where the eyes are more lateral in position, to the anthropoid and human condition, in which the eyes are shifted together near the mid-line in front and can both be focused on an object near by in front of the face. This process of bringing the opposite eyes near each other has been carried even further in the orang-utan than in man, so that the bony partition between the eyes in the orang is excessively narrow.

The eyes of all the anthropoids are very human in character, but especially those of the young gorilla. The back of the eye of the chimpanzee as viewed through an ophthalmoscope[4] is extremely human in appearance, much more than that of the orang, so that this human character of the chimpanzee eye extends even to the arrangement of the blood vessels and the appearance of the pigmented areas.

As everyone knows, the forehead of adult male apes is very low as compared with that of normal men; but the young, both of men and apes, have a swelling forehead. The baby orang-utan shows the domelike forehead of the human infant, and the young chimpanzee[5] has an exceedingly large forehead much like that of a young child. The inference has accordingly been drawn by some authors that the common ancestor of apes and men did not have a sharply retreating forehead but a domelike one and a relatively very large brain case. Although space is lacking to discuss this question, I may be permitted to record my conviction that this inference is quite wrong and that the human race has been derived from large, powerful apelike forms with heavy jaws, massive jaw muscles and a sharply retreating forehead.

The evolution of the human forehead is well suggested if we examine a series of skulls. In an adult chimpanzee skull the forehead is very low and there are heavy ridges over the eyes. In the skull of an Australian black man also the forehead is low and there are well-defined brow ridges. In a modern European skull the forehead is high and the brow ridges are lacking. In the shape of the forehead the extinct ape-man of Java was almost exactly intermediate between the chimpanzee and the lowest known human forehead, that of the Neanderthal race of the Old Stone age. The brain case accordingly has progressively deepened in its vertical diameter, as we pass upward from an apelike stage.

These changes in the contour of the brain case merely reflect the more fundamental changes in the form of the brain which in the higher types becomes excessively voluminous and, as it were, presses out the forehead and skull top in all directions so that in short-headed races of men the head becomes almost spherical in form.

Every part of the bony face of Primates has no doubt been molded in the long run by the action of the facial muscles that press upon it. The partition of bone behind the eyes, for example, has grown downward and outward between the eye and its muscles which lie in front of it, and the powerful jaw muscle (temporal) lying behind it. The cheek bone has been deepened to give a strong support for the outer jaw muscle (masseter). The nasal bones have perhaps been molded to some extent by the muscles on either side of them.

In comparing men and apes one of the greatest differences is seen in the form of the front part of the upper jaw, which is associated with the marked differences in the form of the lips already alluded to, and with certain no less important differences in the character of the teeth and in the movement of the lower jaw. It seems very well established that as the primitive ape-men passed from the semi-erect to the fully erect posture, and as the rapidly expanding brain case became balanced at the top of the progressively uptilted backbone, the whole front part of the jaws and lips was drawn backward beneath the overgrowing front part of the brain case; meanwhile the lower jaw and the whole head increased greatly in vertical height, but shortened equally in fore-and-aft length; the width across the brain case increased, the sockets of the lower jaws moved apart and the opposite halves of the jaws became sharply inclined toward each other, so that the front teeth were all drawn backward; the palate and the lower jaw were thus shortened, and the denta. arches assumed an archlike curve, the crowding of the front part of the jaw being partly associated with the marked reduction in size of the canine and premolar teeth.

A multitude of minor changes and readjustments took place at this critical time, but they were nearly all the direct result of the general tendency to shorten the face and draw it inward beneath the overgrowing, forward expansion of the brain case. Among other important consequences of this general retreat of the face and its bony substructure were the downward and outward growth of the nose and the forward growth of the chin.

The evolution of the chin has given rise to an extensive literature. Some writers ascribe its existence to the excessive development of the gemogniossus muscle, which runs from the hinder surface of the chin into the lower part of the tongue and which throws the tongue into the rapidly shifting positions assumed in articulate speech. Other writers ascribe the outgrowth of the bony chin to the withdrawal backward of the dental arch, to the increased pressure in the chin region, and to the turning outward of the lower rim of the jaw. Others regard the chin, like the nose, as a direct outgrowth, of no great functional importance, but linked in some way with the progressive improvement, according to human standards, in the appearance of the whole face. The present writer has sought to connect all these changes, including the reduction in size of the canines and bicuspids, with a profound change of food habits from the omnivorous-frugivorous habits of forest-living apes to the predatory carnivorous habits of plains-living men.

The profound disturbances and readjustments in the brain, brain case, and face were accompanied by equally far-reaching changes in the backbone and in the pelvis and in the bones and muscles of the limbs. The forearms, no longer used in the stooping posture, shortened, while the legs rapidly lengthened, so that men very early became fast runners on the open plains.

In conclusion, if we compare the skull of a young anthropoid ape with that of a young human being we shall find that every bone in the ape skull may readily be identified in a slightly different form in the human skull; the number and kinds of teeth are the same, both in the milk and permanent dentitions, and even the crown-patterns of the molar and bicuspid teeth are fundamentally similar in primitive apes and men. In spite of all the readjustments following the assumption of the fully upright gait and the change in food habits, the differences between the primitive ape skull and the human skull are essentially differences of proportion and of degree rather than of kind.

From the palæontological viewpoint these numerous and fundamental resemblances can only mean that living apes and men have evolved from a remote and as yet undiscovered common ancestor that lived perhaps in the middle period of the Age of Mammals. I believe also that the living apes, because they have stayed in the ancestral habitat, have retained the greater part of the ancestral man-ape characters, and that the ancestral pattern of the human face may still be seen in little changed state in the faces of young female gorillas and chimpanzees.

[1] Theory put forth by Ruge. This is generally accepted by anatomists as the true explanation of the origin of the facial muscles of mammals.

[2] By Professor J. H. MacGregor, of Columbia University.

[3] Dr. George F. Stevens (*in litteris*).

[4] According to the beautiful colored plates of Dr. Lindsey Johnson. The gorilla is not figured among them.

[5] See illustration from photograph on p. 152.

Mid-Scotland Ship Canal*

THE scheme for the construction of a ship canal between the Clyde and Forth has been advanced another stage by the presentation to a meeting in Glasgow of reports which have been prepared by Messrs. Sir W. G. Armstrong, Whitworth, and Co.

Although the requirements for commercial vessels could be served by a canal constructed on much smaller dimensions than those adopted in these reports, the width of channel and depth of water have been determined with the object of providing for the use of the canal by ships of war, the project being one which is ruled by this primary consideration. The dimensions to which these designs have been prepared are a minimum width at bottom 150 feet, depth of water 45 feet, clear head room under bridges 20 feet, and minimum radius of curves two miles. The detailed surveys which have now been made confirm the opinion previously reached that there are only two possible routes for such a waterway, one along the valley of the river Forth which would reach the deep water channel of the Clyde via Loch Lomond and Loch Long; the other by the valleys of the Bonny and Kelvin direct into the river Clyde below Glasgow. It is an interesting fact that these were the routes selected by the famous engineer John Smeaton, whose reports made in the eighteenth century are still in existence with accompanying plans.

LOCH LOMOND ROUTE.

The report states that in respect of the main object with which the canal would be constructed the Loch Lomond route possesses great advantages, particularly from the point of view of the cost of the work. The total length by it would be 71¼ miles and by the Direct Route 50 miles, but by the latter there would be 48 miles of artificial works against 40¾ miles in the Loch Lomond scheme, while on the whole of the Loch Lomond route there would be only eight miles above the 100-foot contour level, whereas by the Direct Route there would be over 21 miles above that level. Another advantage in favor of the Loch Lomond route is that there are ample supplies of water for lockage and other purposes to be obtained from Loch Lomond.

The route now surveyed starts from the natural deep water channel in the Firth of Forth, which would be dredged over a length of four miles up to Grangemouth Docks. Thence the artificial waterway would be excavated through the Forth Valley for a distance of nine miles, and, passing immediately south of Stirling, it would enter the low ground adjacent to the river Forth and proceed through it for 16 miles to the foot of the ridge which divides the Forth and Clyde Valleys. After crossing the ridge by means of a rock cutting it would pass through the low ground in the valley of the river Endrick into Loch Lomond at a point 35 miles distant from the Forth. The natural deep water channel of Loch Lomond would be used to Tarbet, and by a cutting thence, having a length of 1¾ miles the deep water of Loch Long would be reached at Arrochar. The excavation work would present no special difficulties. An important new engineering feature in the scheme now submitted is the proposed utilization of the surplus waters of Loch Lomond for the purpose of elevating the canal to 25 feet above ordnance datum, thereby saving a depth of 3½ feet of excavation throughout the whole length of the waterway.

RAILWAY AND RIVER DIVERSIONS

Railways would be crossed at only three points, the most important being the Scottish Central branch of the Caledonian Railway, near Larbert. This line would be carried over the canal by means of a fixed bridge and diverted for a length of three miles, and there would be another diversion in the case of the Dumbartonshire Railway over a length of 12 miles. The more important of the two rivers intercepted is the Endrick. This stream, which is subject to very heavy floods, would be carried under the canal by means of a siphon, and the Bannock Burn would be controlled by means of a dam and discharged into the canal. The regulating locks at the Firth of Forth and at Arrochar would be of similar design and would be 1,200 feet in length between the inner gates and 130 feet wide, with a depth of water over the sill of 45 feet.

BRANCH COMMERCIAL CANAL

With the object of providing facilities for commercial traffic between the upper reaches of the Clyde and the new waterway it is proposed to construct a branch canal between Loch Lomond and the Clyde near Dumbarton. This auxiliary waterway, which would follow the line of the valley of the River Leven, would be 7½ miles long, and the suggested dimensions are a width of 100 feet, and a depth of water of 40 feet. One lock only would be necessary, and this would be situated on the foreshore of the River Clyde. It is assumed that a length of lock of from 600 feet to 740 feet, a width of 90 feet, and a depth of water of 40 feet, would meet the needs of commercial traffic. The total quantity of excavation and dredging for this branch canal is estimated at 14 million cubic yards. Vessels entering the canal above the proposed junction with the Clyde would save a distance of 33 miles as compared with the route via Arrochar.

THE DIRECT ROUTE

It is admitted that from the purely commercial point of view a canal constructed via the valley of the rivers Bonny and Kelvin is to be preferred, as it would traverse a rich industrial territory, and the report which has been made on this route shows that notwithstanding the preference expressed for a waterway via Loch Lomond the Direct Route is a feasible if more costly scheme. The canal by this route would start at a point northwest of Grangemouth Docks very near the proposed lock entrance for the Loch Lomond Canal. The line of the Forth Valley would be followed for four miles to near Larbert, the canal passing to the south of that town. It would then enter the high ground east of Bonnybridge and continue in high ground for 20 miles, passing through the continuous valley which is formed by the rivers Bonny and Kelvin, and thence being excavated through a rapidly descending slope to a point on the River Clyde at Dalmuir Lighthouse. It is stated that the line determined upon is such that, consistent with a minimum radius of curves of two miles, the ground is at the lowest level available throughout its entire length between Grangemouth and Clydebank, and for the greater part of the route the line proposed follows closely that of the existing barge canal built by Smeaton.

The total quantity of excavation and dredging involved, omitting dams and subsidiary works, is stated to amount to 253 million cubic yards, as compared with 155 million cubic yards in the Loch Lomond project. Although there would be a smaller quantity of rock excavation involved in this project than in the Loch Lomond route, there would be a much larger quantity of soft excavation, which, according to engineering experience, is in any cutting of 150 feet in depth or over more costly owing to the shallower slopes required than in rock cuttings. A point is also made of the fact that productive coal measures underlie the line of the projected canal at certain places, and that some parts of the limestone coal group would underlie the excavations for the whole length from Grangemouth to Clydebank. The proposal made in the case of the Loch Lomond route to utilize the surplus waters of Loch Lomond to elevate the level of the canal to a height of 25 feet above ordnance datum, would be incorporated in the direct route, by the construction of reservoirs in the valley of the River Carron, which, it is believed, would supply sufficient water to maintain the desired level. In any case, if a sufficient supply of water for this and, indeed, for purely traffic purposes were not brought from an external source it is stated that it would be necessary to excavate the canal down to sea level at a largely increased cost. There would then be two regulating locks, one at each end, and these would be of the same dimensions as those proposed in the case of Loch Lomond route.

SUBSIDIARY WORKS

The Direct Route involves, however, a greater disturbance of existing road and rail communication than the alternative scheme. Railways would be crossed at nine points, four of them being important lines. In the case of two crossed at Clydebank there would be a diversion of a total length of 3.6 miles, by means of two single-line tunnels under the canal. The principal streams which would be crossed are the Carron and the Kelvin; and a number of small diversions of both rivers, including in one case the construction of a siphon, would be necessary. The estimated cost of this scheme is 52 millions sterling, compared with 33½ millions for the Loch Lomond.

Engineering Supplement of the London Times.

Cat Tail Plant in Industry

THE use of the Typha, commonly known as the cat tail, in various industries, is under discussion in France just at present. Deputy Bedouce recently published an article on the subject in the Paris daily press, in which he urged the cultivation of this plant either as a source of cellulose for explosives, or to replace cotton and thus diminish imports into France. An abstract of this article appeared in our columns. More recently, a very complete and technical exposition of the subject has been made by M. Eugéne Collin, chemical expert attached to the Agriculture department, of which we present a summary. The genus Typha comprises seven or eight species, two of which grow in France, these being similar in appearance. Most persons are familiar with the cat tail, which grows in marshy ground, but it should be remarked that during the flowering period the stalk contains two distinct flowers, one on top which consists of a white tuft and forms the male flower; while below it on the same stalk is the female flower or more properly inflorescence; this being the familiar "cat tail" of dark brown appearance and velvety nature. The cat tail is made up of tufts of down which are closely packed together, but when ripe the down separates from the stalk and each tuft floats in the air, carrying a seed, and often reaching great distances. This constitutes the fibers which it is proposed to use in various industries. The author examines the structure and the properties of these fibers, which average 0.4 of an inch in length, and comes to the conclusion that they cannot be well employed in the textile industries, although they can have other uses. Concerning its use as a substitute for cotton as a textile material, he states that it is easy to obtain an abundant amount of down from the plant without needing special machines, but cotton has marked advantages over typha, for it is much longer in fiber or 0.6 to 1.2 inches compared with 0.4 inch, and in cellular structure cotton is superior. Again, the typha down or wadding does not possess uniform composition because of the presence of the small flower stalk in the middle of each tuft along with the seed, even though both of these are very small. However, the seed is large enough to be a drawback in industrial use. It can be separated by a suitable beating with a wooden rod, and the tufts then collect in the shape of down, while the seed falls to the bottom and collects as a coarse powder. But the separation is far from complete, the lower and part of of the stem is sure to remain mixed with the fine fibers. It is also noticed under the microscope that a great number of fibers are broken up by the beating so as to become improper for textile purposes. The author claims that it would be impossible to separate the seed and stems properly without the use of very expensive machinery, and for this and other reasons concludes against its use as a substitute for cotton in textile work, but he considers that it could be used to some extent in manufacture of inferior felt or as a substitute for use in feather beds and light cushions, it could not probably be substituted in the case of sacks or ropes, twine and the like. It might be used instead of jute by avoiding the beating process and employing the entire down. The typha could not replace wool for even more obvious reasons. From the preceding, it will be easily understood why there has been so little previous success in the textile use of this substance, even though it was so well known. But in view of the success which has been obtained by using suitable machines for spinning and weaving of kapok fiber, it is not impossible that typha can be employed for certain textile uses. A question of another nature is the use of typha as a source of cellulose, especially for the preparation of explosives. Experiments are being carried on which show very favorable results.

It must not be supposed that the idea of using typha fiber is a recent one, for manufacturers in different countries were formerly occupied with the question, and it seemed to be dropped afterward as unpractical. Chardin, in his book of travels, mentions that in Persia the typha wadding was mixed with ashes and quicklime to make up a mortar which became as hard as marble. In other places an attempt was made to combine it with rabbits' fur for hat making, and also to weave it along with cotton or silk for making gloves, stockings or fabrics. M. Darat made an attempt to use it for producing a paper resembling Japan paper as far back as 1830. None of these early attempts seem to have met with much success, for in modern works upon textile materials there is hardly any mention made of the typha. Vetillart and Lecomte do not mention it in their works, nor does Höhnel, who is a leading German authority on textile matters, dwell to any extent upon the typha down except to describe the structure of the fiber. During recent years, because of the movement in favor of utilizing natural resources, the attention of manufacturers seems to have been directed towards this product. For instance in his report on the exploitation of marsh lands in Annales du Ministère de l' Agriculture, M. Geze states that typha wadding is utilized in the Danube region and since 1907 it is beginning to have a certain commercial importance. Attempts have been made in France to use typha fiber for paper making, and according to M. Geze there was founded a large company in Rumania which obtained a 30 years' concession for marsh lands in the Danube region in order to cultivate typha for textile fibers. The above remarks will give some idea of the status of the present question, and it will be seen that the industrial use of the typha is one that admits of different opinions.

Focusing X-Rays

Single Wave Length Intensity Increased a Thousand Fold

By L. E. Dodd

In the preceding article on "The Development by X-Rays in Two New Fields," which appeared in the last issue of the Scientific American Supplement, page 140, the new method of analysis of crystals by X-rays was described in some detail. The work in this field is by no means finished. The crystals of many substances remain to be studied. Thus far X-ray analysis of metallic crystals has been limited in amount. A leading difficulty with these is their very small size, making it necessary to study them en masse, which greatly restricts the investigator. The production of large size crystals of the different metals, large enough to be subjected to individual tests, offers a worthy field for the best effort of the scientist.

The element selenium exists in both metallic and non-metallic forms and is outstanding in its electrical-optical properties. In two of its allotropic forms it is an electrical insulator; in its third form, the metallic, it is a conductor, with a conducting power that depends not alone on its temperature, but also on the intensity of the light falling upon it, and on the mechanical pressure applied. To make possible the study from various standpoints of individual crystals of metallic selenium, work was done in the University of Iowa physics laboratory for the purpose of learning how such crystals might be grown. These efforts were well rewarded, as outlined in an earlier article in the Scientific American of Aug. 14, 1915.

One of the tests to be made on such individual crystals is that of X-ray analysis. This work was recently done by Dr. Elmer Dershem, working in the same laboratory. A typical X-ray spectrum, with tungsten target in the X-ray tube, as produced with one of these large crystals of metallic selenium as reflector and photographed by Dr. Dershem, is shown in Fig. 1. Another important test for such crystals is that for possible changes caused by X-rays on their electrical conducting power. Such an effect by X-rays, similar in kind to that by light, and differing from it only in degree, one would in confidence expect from the known similarity of X-rays and light. Mr. A. M. McMahon worked on this problem last year in the Iowa laboratory and found, as anticipated, that X-rays do affect the conducting power of these crystals. But his experimental results were obtained with beams of X-rays having a number of wave lengths present at the same time. Evidently, from data of this limited nature, no very detailed conclusion can be drawn, although it does establish the important fact of a definite effect by X-rays on the conducting power of selenium. But before our knowledge of the action of X-rays on selenium can be at all satisfactory the imperative need is a detailed study of the effect of the rays on individual crystals of this element, carried out as in McMahon's work, but with single wave lengths.

The only method at hand for separating out X-rays of a single wave length (or nearly of a single wave length) is that of interference reflection from a crystal in the X-ray spectrometer, described in the preceding article. McMahon and Dershem showed conclusively, however, that the intensity of such a beam of *single* wave length, as obtained with the X-ray spectrometer, is so low as to cause, when it falls on a selenium crystal, no measureable change in the crystal's power to conduct electricity.

Not only is a monochromatic (single-wave-length) beam of X-rays needed for the further study of selenium, but X-rays in such form should be applied to further research in the field of Roentgenology, the science of X-ray photography on the human body. Of the physiological effects of X-rays all are aware. People have heard of both X-ray "burns" and X-ray "treatments." But the beam of X-rays used by the Roentgenologist contains a number of different wave lengths. It is hardly natural to suppose that each one of these different wave lengths produces the same physiological effects in the same degree as all the others over the whole range of wave lengths present in the beam. The availability of monochromatic beams of X-rays sufficient in intensity for effective study of the physiological effects of different wave lengths should be of definite interest to the research worker in that field.

For these two reasons, then, if for no others, it appeared desirable to be able to focus single wave lengths of X-rays. During his study of selenium crystals with the rays, and in view of McMahon's results showing that single wave lengths isolated by crystal reflection did not possess the intensity sufficient to affect the electrical conducting power of a selenium crystal, the problem of focusing single-wave-length X-rays presented itself to Dr. Dershem. Others had previously made attempts to focus these rays, looking for a solution in vain by methods that had proved hopeless.

Light is focused either by transmission through converging lenses or by reflection from suitably shaped

Fig. 1

concave mirrors. Converging lenses of ordinary matter had been proven by earlier investigations to be powerless in converging X-rays. It appeared to Dr. Dershem that the method of reflection might be used to focus monochromatic X-rays, especially since single wave lengths can be separated by interference reflection from crystals. If a concave mirror could be constructed of natural crystal surfaces one should then be able not only to separate out a single wave length but also to focus it by the mirror method at the same time. Crystal surfaces of large variety are readily obtainable, but for purposes of the required crystal mirror the problem arises of getting such surfaces of concave shape, since they are laid down by nature in planes.

As stated in the previous article, W. L. Bragg had been led to try mica for regular reflection of X-rays because its crystal structure affords such very definite cleavage planes. Bragg's experiment had been eminently successful. Thus mica appeared to be a crystal possessing, most fortunately, the two necessary properties required for making a focusing mirror for X-rays, first, its unusually good reflecting power for these rays, due to its definite cleavage planes, and second, its peculiar crystalline structure, such that it can be split up to an almost unlimited extent along these cleavage planes into thin, flexible sheets suitable for bending to the required degree of concavity. The soundness of Dr. Dershem's idea has been amply confirmed by the results.

Fig. 2

Following Dershem's procedure let us see what conditions are necessary for the focusing of X-rays by interference reflection, or their reflection by crystals. A perfect focusing of either light rays or X-rays means their convergence so that all the rays in the beam shall pass through a single point called the focus, beyond which they again diverge. A perfect focus, or the passage of all the rays through a single point, is rarely attained, even with light rays, so we shall not be disappointed if an absolutely perfect focus is not obtained with X-rays. For light rays a perfect focusing mirror can be *designed*, but for X-rays we are limited, even in design, in a manner not true for light. The reason for this limitation is that "regular" reflection of X-rays does not depend on reflection from a single surface alone, but on the suitable combining of a number of reflected waves having their origin at successive crystal planes. With X-rays it is an interference reflection, as distinct from the simple reflection of light rays. This limitation with X-rays has to do with the glancing

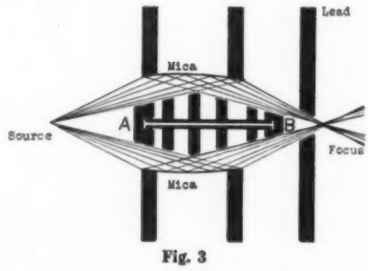


Fig. 3

angle of incidence, and is expressed in the equation (see preceding article) $n\lambda = 2d \sin\alpha$. With a focusing mirror we shall of course be restricted to a single order spectrum. If we are to use the first order spectrum, or the reflected beam corresponding to $n = 1$, we are limited to a definite angle of incidence, α, whose sine is $\lambda \div 2d$. Further, if the reinforced reflection is to be equally good from all parts of the mica mirror, all the rays of the Roentgen beam striking it must do so at the same angle α. This condition is of necessity imposed at the outset. Since mica is the crystal to be used for the focusing mirror the value of d will be the constant known distance between atomic planes in that crystal. λ is the single X-ray wave length to be focused. It will be one of the characteristic wave lengths of the metal composing the target in the X-ray tube. Now, as Dr. Dershem states, it is known that mica reflects strongly a certain wave length of the tungsten X-ray spectrum (tungsten used as target) at the glancing angle, α, of 11° 15′. Since we wish the best possible experimental conditions in the first mirror to be constructed we must choose this particular value of λ, and thus, through the equation, we have fixed 11° 15′ as the value of α.

X-rays issue in a divergent pencil from a restricted area on the target of the X-ray tube. This is the area occupied by the spot focus of the cup-shaped cathode giving off the exciting cathode rays, or in the newer Coolidge tube the small area where a beam of converging electrons strikes the target. The X-rays issuing from this area on the target may be regarded, for the purposes of our design, as coming from a point source, S. (Fig. 2.)

The problem presented by the design is simplified at the outset if we fix our attention on some particular plane that contains the point source S and another point F that is to be the focus. Our object is to find some shape of reflecting surface that will cause all rays coming from the point S to pass, after reflection, as nearly as possible through the point F. If we draw in the plane a curve for which all rays coming from S will, after "regular" reflection (angle of incidence equal to angle of reflection), pass through the point F. we can then rotate this curve about the straight line joining S and F as axis. In this way we describe a surface of revolution. Such a surface will afford the greatest possible reflecting area and thus the highest possible intensity of the beam at the focus. The surface of revolution will be a barrel-shaped figure, which must be replaced by an open-ended "barrel" (Fig. 3) of mica that is to play the part of concentrator for the X-rays. The rays from the source are to pass into this barrel at one end, to be reflected from the interior walls, thence to pass out of the barrel at the other end in a converging beam that is focused at F. (Figs. 2 and 3.) The direct rays from the source that would otherwise pass through the barrel without striking the interior walls must of course be screened off.

We require the equation for the plane curve that is to be used for generating the shape of our crystal mirror. At the outset we are limited, as already seen, to a definite angle of incidence, α, which must remain constant for all the rays from S that strike the plane curve. In other words, all straight lines drawn in the plane from the source S to the curve must strike the curve at the same glancing angle α. This condition fixes the kind of curve required. The curve having the property of meeting always at the same angle all straight lines drawn to it from a certain point is a logarithmic spiral, so that the curve we are to use in generating our surface of revolution is a segment of such a spiral.

But since the type of curve is now definitely fixed by the imposing of one arbitrary condition necessary for the fullest success in focusing the rays, it is impossible to impose the further condition that the reflected rays shall all pass through a given point, or that they shall have any arbitrary directions whatsoever, for the law of regular reflection will operate and we must be content to let the reflected rays fall where they will. If we were to impose the condition that all the reflected rays must pass through a given point we should require a logarithmic spiral segment similar to the one already introduced, but turned end for end. Evidently we cannot use two different curves at one and the same time. Happily, however, by using a relatively short segment of the spiral already introduced—a segment very nearly

symmetric—we can make the reflected rays pass approximately through a common point, as can be shown by graphical construction, and this point thus becomes our focus, F.

In polar co-ordinates the general equation for the logarithmic spiral is

$$\log \rho = \Theta \cot \alpha + C,$$

where ρ and Θ are the polar co-ordinates, α is the constant angle chosen for the spiral, and C is an arbitrary

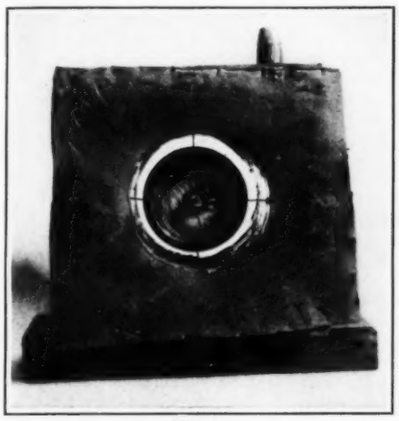


Fig. 4a

constant. We choose the constant C so that when $\Theta = 0$, $\rho = 10$, which does not affect the generality of the result, but merely rotates the curve about the origin. This value of C is 2.30259. Then our equation for the spiral becomes

$$\log \rho = \Theta \cot \alpha + 2.30259.$$

Or, using common logarithms,

$$\log_{10}\rho = .00758\ \Theta \cot \alpha + 1,$$

where Θ is now the polarizing angle *in degrees*. The last equation is our working formula, to be used in conjunction with the equation, $\lambda = 2d \sin \alpha$, for X-ray reflection of the first order. This expression is general since d is determined only by the crystal used for the focusing mirror, and λ by the particular wave length it is desired to focus. For the best of reasons, however, we have already chosen mica as the crystal, and a particular value of λ from the tungsten X-ray spectrum. Dr. Dershem worked with a Coolidge X-ray tube, which has a tungsten target. For this value of λ the value of α is 11° 15′. Thus the logarithmic spiral to be used for our purpose is obtained by substituting this value of α in the working formula, and plotting a suitable length of the spiral. We shall of course wish to make it as long a segment as possible without causing too much "fuzziness," or spreading of the spot focus. We must therefore seek a balance between intensity of the reflected beam at the focus, and sharpness of the focus. Greater intensity is gained by increasing the length of the generating spiral segment, thus increasing the reflecting area, while greater sharpness is gained by just the opposite procedure, that is, shortening the spiral segment. The designer must judge from a preliminary graphical construction what is the best length of segment to be used.

A cross-section of the finished concentrator indicating the method of its use is given in Fig. 3. The rays that would pass directly through the concentrator without reflection from the mica walls are cut off by means of lead screens inserted as shown in the figure. The central tube lying along the concentrator axis, with its caps A and B, is for the purpose of "sighting" the instrument. Two pairs of cross-wires are fastened over the ends of this central tube, one pair at each end, with their intersections falling on the axis. One pair of cross-wires may be seen in Fig. 4. The operator sights through the horizontal tube towards the source, which, as already pointed out, is a small area on the target of the X-ray tube, bringing the concentrator into such a position that the two cross-wire intersections and the source fall in the same straight line.

The distance from source to nearest end of concentrator necessary to give the required angle α is known from the preliminary graphical construction. The focus of the concentrator can then be quickly located, with the X-rays turned on, by means of a fluorescent screen, which will show a small spot of light of maximum brightness and minimum size when placed accurately at the focus.

The first crystal-mirror X-ray concentrator made was constructed in the following manner. After plotting the desired length of logarithmic spiral Dr. Dershem determined the position of the focus graphically. The line joining this point and the source was the axis of symmetry of the concentrator. A wooden form was then turned out in a lathe, being gradually shaped, by the "cut and try" method, so that it had finally the required dimensions of the surface of revolution generated by the spiral segment. Over the wooden form were laid flexible sheets of mica crystal bent to shape and held in position by strips of paper glued to them. The whole was then surrounded by melted paraffin, which on solidifying gave a cast of the wooden form. Later this form was removed.

Photographs of this first concentrator to be built are presented in Fig. 4, which shows the paraffin cast holding the mica sheets firmly to its inside walls. Although it appears to be a contrivance very rudely built, nevertheless great pains were taken with the important features of it, and results were obtained that could never be improved by mahogany finish. (a) gives an "end-on" view through the concentrator showing the lead screens, *in situ* inside the apparatus, whose purpose is the cutting off of the rays that would pass directly through without reflection from the mica walls. A large lead screen over the end prevents rays from passing through the paraffin. (b) is a similar view of the opposite end. (c) is an oblique view of the same

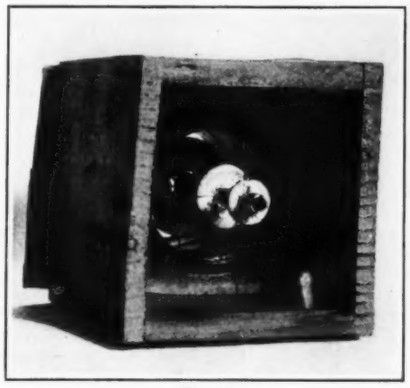


Fig. 4c

end, showing lead cap removed from the central tube. The cross-wires over the end of the central tube for "sighting" are seen in (a) and (b). The diameter of the open end of the concentrator is about 2⅛ inches, and the length of the concentrator proper (not of the wood box) is about 3¾ inches.

In locating the position of the spot focus, after the concentrator has been "sighted," a fluorescent screen is used as already described. If the fluorescent screen

Fig. 5

is replaced by a photographic plate the plate will be affected, and there results a photograph of the spot focus. Such a photograph is shown in Fig. 5. Referring to it, Dr. Dershem states that "the dark spot is large because the X-ray tube used had a rather large focal spot, when for the best results a tube with a fine focus should be used. * * * The photograph was taken from the side of the tube and shows the oval image of the (circular) focal spot of the anticathode."

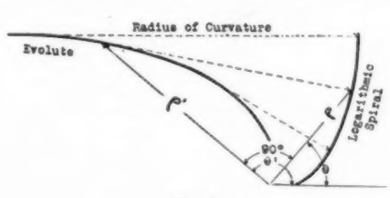


Fig. 6

That is, a circular spot when observed from any direction other than perpendicular appears oval, and in the case of this photograph with the X-ray concentrator we have virtually an oval source. The intensity of the single wave length which mica reflects strongly at a glancing angle of 11° 15′ was increased by the concentrator, where the area of the reflecting surface was 160 sq. cms., a thousand-fold over that possible with a plane crystal. An impression can thus be obtained on a photographic plate in a few seconds that would require hours by the usual method of crystal reflection.

Regarding future applications of the crystal mirror concentrator, again in the words of Dr. Dershem, "It seems probable that equal amounts of energy from different parts of the X-ray spectrum would have very different effects in changing the resistance of selenium and also in the physiological effects which X-rays exert

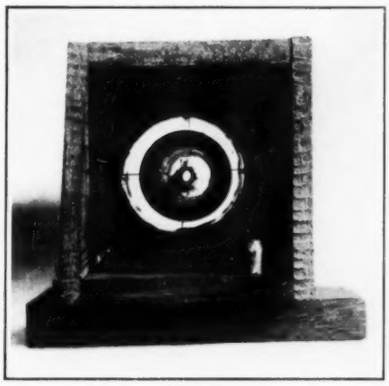


Fig. 4b

on all living organisms. * * * It is hoped by this means to unfold many of the properties of characteristic X-rays which would remain hidden without this aid to research."

To conclude, Dr. Dershem has indicated a practical method for the construction of concentrator forms to be used in making the paraffin casts, a method desirable both for time saving and for reduction of error. This method employs the evolute curve of the generating spiral. The evolute of a logarithmic spiral is another logarithmic spiral (Fig. 6). The equation of the evolute is

$$\log_{10}\rho = (.00758\ \Theta - 1.5708)\cot \alpha - \log_{10}\tan \alpha + C,$$

with Θ in degrees. This is obtained by the substitution of $\rho = \rho' \tan \alpha$, $\Theta = \Theta' - \pi/2$, in the equation for the involute spiral, which is our generating curve. The evolute is plotted with polar co-ordinates to the proper scale. A form is then made which fits the evolute as nearly as possible. A thin steel strip is bent around this form. The strip is kept stretched, and as it unwraps from the form it regulates the distance of a cutting tool from the curve of the evolute. The mechanism is attached to a lathe in such a way that the path of the cutting tool is that of the required logarithmic spiral, so that the surface of revolution cut out on the lathe has the necessary shape. The decrease in error by this method is due to the fact that "an inaccuracy or displacement of a point in the curve of the evolute will cause a much smaller displacement than itself in the position of the tracing end of the strip, thus giving a smoother and more accurate logarithmic spiral surface of revolution." This will be clear from the figure (6) showing the generating logarithmic spiral segment and its evolute.

The Real Dermatology

LEONARD WILLIAMS, in *Medical Press and Circular*, says that the efficiency of the skin as organ of drainage is directly dependent upon the thyroid gland. When that gland is at fault, the fact is immediately reflected in the integument, which becomes dry and generally scaly. In the present day therapeutics of all skin lesions—as indeed of most other conditions—too much is made of the microbe and too little of the soil. So far as the skin is concerned, its health is so intimately dependent upon the thyroid that it is almost safe to say that this little gland contains all the cutaneous laws and most of the prophets. Radcliffe Crocker tried to express the riddle of dermic disease in terms of the thyroid. That he was only very partially successful was not altogether his fault, for he was betrayed by fashion into giving to human beings with slight thyroid insufficiency doses of thyroid extract which had been found suitable for apes which were entirely thyroidless. If the dermatologist of today would wipe that particular slate clean and recommence the study of the question on the basis of small initial doses, not only of thyroid extract, but also of the extracts of other endocrine glands, he would not only contribute much of real value to the therapeutics of skin diseases, but he would do something to throw light on some of those wider fields of dermatological inquiry to which the writer has, with ostensible levity, but with a real underlying humility, ventured to direct your attention.

Meteorology and Aeronautics*

Physical Properties and Dynamics of the Atmosphere

By William R. Blair

ATMOSPHERIC CONSTITUENTS

APPROXIMATELY 78 per cent., by volume, of the air near the earth's surface is nitrogen and 21 per cent. oxygen. Another diatomic gas, hydrogen, is found uniformly distributed, but in very small quantity. The monatomic gases, argon, neon, helium, krypton, and xenon, are present, their volumes being in the order given. Other gases and vapors of more complex molecular structure and less uniformly distributed are water vapor, carbon dioxide, ammonia, and sulphur dioxide. The last three gases named are hygroscopic and seem to exist in the atmosphere in association with more or less water, depending on the amount of atmospheric moisture available. Other gases, as well as dust of both terrestrial and meteoric origin, are present in varying quantities, depending on the time or location in which observations are made.

DISTRIBUTION OF CONSTITUENT GASES IN THE ATMOSPHERE

In order of their atomic weights the first eight of the gases mentioned are hydrogen, helium, nitrogen, oxygen, neon, argon, krypton and xenon. When molecular weights are considered, neon is third in the list, and nitrogen and oxygen fourth and fifth, respectively. It is probable that these gases are sorted by gravity and that, as the distance from the earth's surface increases, the proportion of the lighter gases increases until at some height, 150 kilometers or more above sea level, the chief constituent of the air is hydrogen. Convective mixing of the air interferes with this sorting to some extent, especially in the lower 10 kilometers of the atmosphere.

NUCLEATION AND CONDENSATION

Recent observations and experiments indicate that the hygroscopic gases, rather than dust or ions, furnish the nuclei upon which the water vapor of the air condenses, forming haze and fog or cloud. Strata of air that are hazy are found to be rich in these hygroscopic nuclei and usually a disturbance that elevates such strata either in whole or in part results in cloud formation. It may happen that the temperature of the air in the haze layer is lowered without accompanying change of level, with the result that a stratum of cloud replaces the stratum of haze. When air of the haze layer is forced up in places by a relatively strong vertical component in its motion, the resulting type of cloud formation is cumulus; when it is cooled, either by being elevated as a whole or by other means, the type of cloud resulting is stratus. The formation of cumulus clouds therefore accompanies turbulent atmospheric conditions, and is in turn an indication of these conditions.

PRESSURE AND UNITS OF MEASUREMENTS

Atmospheric pressures are most familiarly measured in inches or millimeters of the height of a column that will just balance the static pressure of the air at a given place. Thus, the standard pressure commonly designated one atmosphere is a column of mercury 760 millimeters high having a temperature of 0° C. under gravity at sea level and latitude 45°. The pressure of the atmosphere and local differences in these pressures are forces capable of causing flow and motions of the air. In order to be able readily to compare these forces with other forces with which we are familiar it is most convenient in all aerological studies to express the atmospheric pressure in dynes per square centimeter, which is the unit commonly employed for the measurement of pressure. Meteorologists generally have agreed upon the distinctive name "bar" for the unit for measurement of air and similar gaseous pressures when expressed in absolute units. A pressure of one bar is a force of 1,000,000 dynes per square centimeter of area. It is exactly equivalent to the pressure of a mercury column of 750.016 millimeters at 0° C. and reduced to standard gravity at sea level and latitude 45°. The familiar standard atmosphere of 760 millimeters equals 1.0133 bars.[1] The millibar (mb.), *i. e.*, 1,000 dynes per square centimeter, is the customary subdivision of the absolute unit, and in a barometric measurement is about three-fourths as large as the familiar unit "one millimeter of mercury." Accordingly, pressures will hereafter be expressed in millibars. Sea level pressure will range roughly between 995 and 1,060 millibars.

AIR TEMPERATURE AND VERTICAL MOTION

The ratio of their specific heats at constant pressure, Cp, and at constant volume, Cv, $\gamma = \frac{Cp}{Cv}$ varies for the different constituent gases of the atmosphere, being about 1.3 for the group in which the molecules are triatomic or more complex, 1.41 for the diatomic group and 1.66 for the monatomic group. For dry air γ is approximately 1.41. In the well-known equations for adiabatic changes, in which V, T, and p stand for volume of unit mass, absolute temperature and pressure respectively,

$$\left(\frac{V_0}{V_1}\right)^{\gamma-1} = \frac{T_1}{T_0} \text{ and } \left(\frac{V_0}{V_1}\right)^{\gamma} = \frac{p_1}{p_0},$$

suppose the subscripts 0 and 1, respectively, represent the conditions, at two stations in the free air on the same vertical line, of an air mass that moves from the lower to the upper station without appreciable loss or gain of heat from outside sources. If we put $\gamma = 1.41$, $v_0 = 1, T_0 = 273$, $p_0 = 1000$ mb., and $T_1 = 272$, and solve for p_1 in millibars, we get

$$p_1 = 1000\left(\frac{1}{\sqrt[41]{\frac{273}{272}}}\right)^{1.41} = 987.5.$$

Substituting these values of p_0 and p_1 in the standard equation for difference in height, $z = k \log \left(\frac{P_0}{P_1}\right)$ it is found that the vertical distance between the stasame vertical line, of an air mass that moves from the tions is 100.5 meters. An air mass cools 1° C. therefore, in ascending approximately 100 meters, and of course warms up 1° C. in descending the same distance. This statement is true only if no exchange of heat occurs either to or from the air mass with the outside and if no latent heat of condensation or evaporation enters into consideration.

LOCAL HEATING

In passing through the atmosphere to the earth's surface the sun's radiant energy is considerably diminished by reflection from the upper surfaces of clouds and from other boundary surfaces that may exist between strata of different densities or constitution. There is some diminution of this energy because of direct absorption by the gases of the atmosphere, but the amount thus absorbed is relatively small. In general, the sun's rays are somewhat refracted by the atmosphere, and the amount of heat reaching the earth by means of them is thus somewhat increased. Locally, the amount of heat received from the sun by the earth's surface may be increased considerably by reflection from the sides of clouds, and it may, of course, be diminished in the cloud's shadow. Insolation, the heating effect of the sun's rays measured at the earth's surface, is considerably greater in the spaces between cumulus clouds, for example, than under "normal" conditions, when there are no clouds present. The air itself when dry absorbs but little of the sun's energy, and is therefore but little heated by the direct rays of the sun. The earth's surface reflects more or less of the solar radiation reaching it, depending on the nature of the material forming it. Snow, ice, water, and white sand, clay, or rock surfaces reflect more of the sun's radiation than do black, brown, or vegetation-covered fields. The color of the surface is determined by the wave lengths it reflects most—a white surface reflects all wave lengths equally, while a black surface absorbs all wave lengths and reflects none. Surfaces that are good absorbers are good radiators, *i. e.*, lose their heat readily by radiation. Surfaces that absorb less readily "hold their heat," *i. e.*, are not good radiators. There is, however, less difference in the rapidity with which these different surfaces communicate their heat to the air by conduction.

SOURCES OF ATMOSPHERIC HEAT

Altogether, cloudiness and other factors considered, less than half the radiant heat from the sun entering the outer portion of the earth's atmosphere succeeds in penetrating to the lithosphere, where it becomes effective in heating the earth's surface and the air near it. Notwithstanding this absorption, however, the atmosphere as a whole is but little heated by the direct rays of the sun. It is the earth's surface that is the chief source of atmospheric heat, and, as has been shown, this surface locally and in point of time receives varying amounts of heat from the sun. This means that locally and in point of time the temperature of the earth's surface varies. The surface temperature in a field of black earth is somewhat higher at 4 p. m. of a clear day than is that of a green pasture adjoining it, and decidedly higher than that of a field of white wheat stubble in the same vicinity. At 4 a. m. these relations of temperature are reversed. Similar but more marked differences of temperature are found between land and water surfaces. To these must be added the temperature variations accompanying elevation and latitude of the surface considered.

CONDUCTION AND CONVECTION OF HEAT.

The earth's surface heats or cools the air in contact with it largely by conduction. It follows that air temperatures at lowest levels will vary in the same sense as do the temperatures of the earth's surface, but not necessarily to the same extent. Convection processes in the air will then distribute the heat. During insolation the air lying on the earth's surface is likely to be receiving some heat from the earth by conduction; at night it is likely to be giving up heat to the earth. As water is evaporated from lakes, etc., the heat of evaporation is furnished by the earth's surface, and this heat is supplied to the air at higher levels as heat of condensation when the moisture condenses; e. g., wherever fog or cloud forms or wherever condensation of vapor yields any form of precipitation.

RADIATION AND ABSORPTION OF HEAT

The proportions of the constituent gases in the atmosphere at any point exert some influence on the air temperature at that point. If a given level in the atmosphere is considered the inflow through it of energy from the sun and the outflow through it of energy from the earth's surface and from that part of the atmosphere below the level in question are, in the long run, equal. This energy is either transmitted through the atmosphere without heating it or is, to a greater or less degree, passed along by the process of absorption and re-radiation. In the latter case the air is heated to such a temperature that equilibrium is established between the rates of absorption and re-radiation. This temperature is different for the different atmospheric constituents, being proportional to their abilities to absorb solar and terrestrial radiation. While the amount of solar radiation absorbed in its passage down through a clear atmosphere to the earth's surface is relatively small, about two-thirds of this amount is absorbed by the water vapor of the air. On the other hand, a large percentage of terrestrial radiation is absorbed as it flows out through the atmosphere and most of this absorption again is by the water vapor of the air. The earth's surface is therefore to be thought of as by far the most important source of atmospheric heat. When temperature distribution in the atmosphere is thought of from this point of view, the earth's surface temperature, i. e., the earth's potential as a radiator, must be taken into account.

AIR MOVEMENT

The density of adjacent portions of stationary free air in equilibrium under the attraction of gravity varies in a definite way from one surface or stratum to the next higher or lower one, but the density tends to be uniform throughout one and the same surface, which may therefore be called an equigravic surface. An equigravic surface as applied to atmospheric conditions passes through portions of the air having the same gravitational potential. Arrangements of air densities not in conformity with the foregoing requirements are accompanied by motions. The denser portions of air, being pulled down by gravity, spread out, partially mingle and replace the less dense portions, which are

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†Member of Subcommittee on Relation of the Atmosphere to Aeronautics, in charge Aerological Investigations, U. S. Weather Bureau; later commissioned Major, Signal Corps, U. S. R.

[1]For derivation of these relations and tables see Monthly Weather Review, April, 1914, p. 230.

pushed up, but are commonly said to ascend, and may also intermingle and spread out until equilibrium is established. Both vertical and horizontal components of motion are necessary in restoring equilibrium. If the composition of the air moisture contents, etc., were exactly the same over a considerable extent, then equigravic surfaces for a state of equilibrium would be horizontal surfaces.

The density of air at constant pressure depends largely on its temperature, but to an extent also on its constitution. In the lower strata of the atmosphere moisture is the only constituent whose quantity varies sufficiently to affect air density appreciably. It has been shown above not only that air temperature varies from point to point in the atmosphere but that the moisture content also varies. Usually temperature and moisture content affect air density in the same sense, i. e., an increase in either makes the density less. Near the earth's surface, where the moisture content and the temperature of the air are rather directly controlled by the nature of that surface, maxima and minima of air density may be found within a few meters, or even a few centimeters, distance. Farther away from the earth's surface these maxima and minima of density are farther apart. Whatever the dimensions of the air mass considered, therefore, it is likely to contain one or more complete circulatory systems in process of adjusting the differences in density of its parts; and it itself is likely to be moving, in conformity with the need for similar adjustment on a larger scale.

CONVECTIVE SYSTEMS

In the process of adjusting these differences in atmospheric density still another factor in the distribution of temperature is introduced. Air masses, with their heat content, are carried bodily from place to place without change of level and consequently with comparatively little change in temperature, volume and pressure. Air masses also change level which entails change of pressure and volume. Work is done when the volume of a given mass of air is changed. When its volume increases, the energy for this work must be furnished either by outside sources or by the gas itself; when the volume decreases, energy is given to outside objects or to the gas itself. When the energy is all supplied by or to the air mass itself, the temperature change in the air mass is 1° C. per 100 meters, as has been shown above. It is clear that the total heat content of the atmosphere cannot be changed by these motions of the air, for under the conditions of our atmosphere as much air must go up as comes down and, if air moves from the point A to the point B, air from B, or air displaced by air from B, etc., moves to the point A. Because quantities of heat are carried about in these circulatory systems and also because temperature differences are the prime causes of the differences in density giving rise to them, they are often called convective systems.

ASCENDING AIR

An ascending air mass may have the energy required for its expansion furnished in part by absorbing radiant heat and by the heat of condensation of water vapor that may take place within it. It will lose some heat by conduction to adjacent air masses, by mixture of air near its boundaries with air of these masses, and by radiation. The percentage of the required energy which may be furnished by absorption (conduction and radiation also included) depends on the rate of expansion or of ascent of the air mass. It is always small and probably not considerable, except for rates of ascent well below 1 meter per hour. The percentage of required energy furnished by heat of condensation of water vapor may be as high as 60 or more after condensation begins, depending on the amount of water vapor present. When precipitation occurs, the net result, so far as air temperature is concerned, is the transfer to the air, in the condensation level, of energy originally derived from the earth's surface when the water forming the precipitation was evaporated.

DESCENDING AIR

A descending air mass may furnish heat to adjacent air masses by conduction, to objects or air at a distance by radiation, or it may supply heat of evaporation to water suspended in it as mist or cloud. Some radiant heat may be absorbed by the air mass as it descends. The conduction effect is small. The absorption and radiation effects are smaller than in the case of an ascending air mass, because of the relative dryness of the descending air mass. The amount of heat of condensation supplied to ascending air is, of course, far in excess of the heat of evaporation given up by descending air. It follows that the adiabatic rate of decrease in temperature with height, i. e., 1° C. per 100 meters is more nearly realized in descending than in ascending air currents.

EXTENT AND RATE OF AIR MOVEMENT

When any convective system is considered, the extent of horizontal motion in the air affected is determined by the horizontal distance apart of the maximum and minimum air densities of the system and on the direction of the motion between these two points. The extent of the vertical motion in any system depends on the condition of equilibrium[3] of the air mass involved and on the magnitude in any equigravic surface, of the difference between the maximum and minimum of air density. The rate of motion either horizontal or vertical depends on the rate of change of density in any equigravic surface of the system. Compared with the rates of horizontal air movement observed, vertical motion is very slow. Horizontal movement of 25 meters per second is frequently recorded, especially at some distance above the earth's surface, and rates of three times this have been observed. It is estimated that over the thermal equator the air is rising at the rate of about one meter per hour. Rates of vertical motion as high as 4 or 5 meters per second may occur locally; e. g., in the deeper cumulus clouds.[4]

ATMOSPHERIC EQUILIBRIUM

The condition of equilibrium of the atmosphere or any part of it depends on the vertical distribution of its perature (defined below) rather than actual temperature the vertical distribution of temperature is the best direct indication of the equilibrium. If potential temperature (defined below) rather than actual temperature is considered, the relation of temperature to equilibrium becomes more direct and apparent. The potential temperature at any point in the atmosphere is the temperature, expressed on the absolute scale, which would be assumed by the air about that point, if this air were changed adiabatically to standard pressure. The potential temperature of a gas, like its entropy, remains constant throughout a reversible or strictly adiabatic cycle of changes and increases for an irreversible process. When in any region of the atmosphere the rate of fall of temperature with altitude is 1° C. per 100 meters, i. e., the adiabatic rate, the potential temperature is constant throughout the region and the state of equilibrium is neutral. If now, in the upper part of this region, the air density increases by an amount such that the additional pull of gravity on account of this increase in density is sufficient to overcome friction, downward motion will result. On the other hand, if air in the lower part of this region decreases in density by a sufficient amount, upward motion will result. In either case a state of unstable equilibrium is brought about. Since in the free air density varies quite directly with temperature, this unstable state is accompanied by a temperature-altitude relation of more than 1° C. per 100 meters or by a decrease of potential temperature with height. When the potential temperature increases with height, i. e., when the temperature-altitude relation is less than the adiabatic rate for dry air, the state of equilibrium is stable, and the degree of stability is indicated by the rate of increase of potential temperature with height. In a region of neutral equilibrium, air in low levels, which becomes warmer, that is, less dense than its environment, will, barring friction, ascend indefinitely to the top of the region in question or until its excess of heat is lost by radiation or exchange with its surrounding air. Similarly, in the higher levels any portion of such air which becomes cooler or denser than surrounding portions will descend to the bottom layers unless stopped by loss of its excess density due to heating from without. When the equilibrium is stable warm light air can rise but a limited amount and then come to rest, because it soon enters strata having the same temperature and density as its own. Similarly, cold heavy air in the higher levels of a stable system can descend but a limited distance before it comes to rest in a stratum of its own temperature and density.[4]

VARIATIONS IN ATMOSPHERIC EQUILIBRIUM

As a whole, and on the average for any particular region, the atmosphere is in stable equilibrium. It is only for limited times and regions that neutral or unstable states of equilibrium exist. The neutral and unstable states are found most frequently during insolation and near the earth's surface. They may extend to the 2-kilometer level and in some cases higher. In general, stability increases with latitude. The air is in more stable equilibrium in winter than in summer and at night-time than during insolation. This is especially true of the stratum in which turbulence is most likely to occur. On a clear, quiet summer day it is often possible to observe the process of conversion from stable to neutral and unstable equilibrium of the air in the lower stratum. As insolation heats the earth's surface, the air in contact with that surface becomes heated and to such an extent that its potential temperature is higher than that of the air immediately above it. The result is the descent and spreading out of the air of lower potential temperature and the ascent and spreading out of the air of higher potential temperature. The vertical extent of this circulation is but a meter or two at the start and gradually increases with the increase in the temperature of the earth's surface. It often happens that the air within the neutral or unstable region is hazy compared with the air above it. To one on a hill or mountain top this haze level is distinctly visible by the time it has risen well above the tree and house tops and its upward progress can be noted. The term "haze level" is a natural one because, to the observer, the boundary between the air in stable and that in unstable equilibrium is clearly defined and appears to be very approximately level. The rate of rise of the haze level for given conditions of the earth's surface seems to vary inversely with the stability of the air above it. i. e., inversely with the rate of increase of potential temperature with height. Consequently, the height to which turbulence of this sort can attain in a given region, by the time the earth's surface has reached its maximum temperature for the day, varies inversely with the stability of air over this region when insolation began. This height has been found to be about 1 kilometer above the earth's surface for a clear winter day and 1.5 kilometers for a clear summer day, at an inland location and over open farmed land in which are occasional patches of timber.

TYPES OF CONVECTIVE SYSTEMS

The type of convective system thus far considered is one which has its origin in a difference of air density over a given equigravic surface. Illustrations of this type of convective system are the planetary system of convection, the diurnal system, and those currents set up because of differences in the nature or elevation of the earth's surface, such as land and water systems, mountain and valley systems, also of combinations of these. These systems are essentially local, either in point of time or location on the earth's surface. In addition to these, there are traveling convective systems, such as those attending maxima and minima of pressure as they pass from west to east, hurricanes, thunderstorms, and tornadoes, the origin of which cannot be so directly or completely ascribed to a difference in density over an equigravic surface.

DEGREE OF REVERSIBILITY OF ATMOSPHERIC PROCESSES

Irreversibility in atmospheric processes may result largely from change in the constitution of the air concerned in the processes, but also in some measure to the absorption and radiation of heat by this air. So far as the atmosphere has been explored, the constituent most concerned in this change, as well as the one responsible for a large percentage of the absorption and radiation of heat by the air, is water vapor. Great changes in water vapor content occur, as a rule, only in the first 3 or 4 kilometers of the atmosphere. In this region, therefore, processes are least nearly reversible.

Complete reversibility of atmospheric processes seems to be more closely approximated, as distance from the earth's surface increases. If the changes taking place within a convective unit are reversible, the unit is self-

[3] The condition of equilibrium of any system under the influence of any force whatever is stable if, when slightly disturbed from its position of equilibrium, its potential energy is increased, neutral if its potential energy remains unchanged, and unstable if its potential energy is decreased. An air mass in equilibrium under the action of gravity is in stable equilibrium free-air gradient of temperature and its influence on vertical direction, its potential energy is increased, neutral if its potential energy remains unchanged, and unstable if its potential energy is decreased, i. e., in addition to overcoming the inertia of the disturbed part of the air mass, the disturbing force must do work on this part of the air mass, in order to effect its change of level, if the air mass be in stable equilibrium, no work is done, either by the disturbing force or by the part of the air mass changing level if the air mass be in neutral equilibrium, and work is done by the part of the air mass disturbed if the condition of equilibrium of the air mass be unstable. In other words, the atmosphere, in its average condition of equilibrium (see par. 15, following), more or less strongly resists vertical motion, depending on the degree of its stability.

[4] C. F. Brooks states (M. W. R., July, 1917, p. 363) he measured 7 m/sec. at Blue Hill, Mass.

[4] It is highly important that the foregoing basic principles governing motions of portions of the atmosphere and its equilibrium be thoroughly comprehended and mastered by the student. Furthermore, in considering circulation in the free air, constant attention must be given to the existing and actual free-air gradient of temperature and its influence on vertical motions under gravitational forces.—C. F. M.

contained and independent of adjacent units. If these changes are irreversible, the unit is not independent of similar adjacent units and their airs mix to an extent depending on the degrees of irreversibility in the units concerned. If the processes in the convective unit represented by the trade and anti-trade winds were reversible, the air of the anti-trades would all have returned to the trades by the time it had reached the northern limit of the trades (confining the illustration to the northern side of the thermal equator). The air of the anti-trades is not able to return directly to the trades largely because its constitution differs from that of the air in the trades. Much of it therefore moves on to the north on the earth's surface and either returns to the trades from higher latitudes or replaces air of another convective unit which in turn must supply some air to the trades. This condition results in the passing of more or less oppositely directed air currents on the earth's surface, the air in these passing currents being as a rule quite differently constituted. There are many ways in which the passing of differently constituted airs in nearly oppositely directed currents is brought about. In the tropics, for example, where insolation is high, a local land and water convective system may create air currents counter to the prevailing trades.

INFLUENCE OF THE EARTH'S ROTATION

Because of the earth's rotation, air (or other matter) in horizontal motion over the earth's surface is acted on by a deflecting force, to the right in the northern hemisphere, to the left in the southern hemisphere. This force is $2w\ mV \sin \gamma$; where w is the angular velocity of the earth's rotation (i. e. $\frac{2\pi}{86164}$), m is the mass of the body acted on, V is the speed of motion of the body, and λ is the latitude. It is important to note that this force is zero at the Equator, but increases to $2wm\ V$ as the poles are approached.

If, then, a current of air is flowing along a straight line on the earth's surface (i. e., along a great circle) in a frictionless manner at a uniform speed, this deflective influence due to the earth's rotation must be balanced by an equal and opposite force. This last is due to the pressure gradient in the atmosphere, which is by definition perpendicular to the isobars. It follows, then, that the current of air must be along a path exactly at right angles to the gradient, that is, parallel to the isobars. It is seen without difficulty that this pressure gradient $\frac{\Delta p}{d} = 2\rho wV \sin \lambda$, where ρ is the density of the air. Taking λ 45°, the pressure gradient across an air current moving at 11 m.p.s. is 1 1/3 millibars, or 1 mm. of mercury, per 100 kilometers, or approximately 0.1 inch of mercury per 158 miles. Eleven m.p.s. is the mean wind speed for the year, observed about 300 meters above the surface at Mount Weather, Va. Actual speeds may depart far from this mean in either sense. Summer winds are, as a rule, slower and winter winds faster than this mean.

If the current of air has a constant speed V in a circle of radius r, there must be a force acting on each particle of the air in toward the center of curvature equal to mV^2/r; the deflective force due to the earth's rotation acts in this direction in an anticyclonic system (i. e., a "high") in the northern hemisphere and opposite to this direction in a cyclonic system (i. e., a "low"). It follows at once that the force due to the pressure gradient must be radially out in a high, and radially in in a low, and that therefore the lines of flow of the current are parallel to the isobars. It is obvious, then, that in order to have a uniform flow at speed V, friction being assumed negligible, in a curve of radius r, V must satisfy the following condition:

$$\frac{\rho V^2}{r} = \pm \text{ (pressure gradient } - 2\ \rho w\ V.\ \sin \lambda),$$

where the plus sign applies to a cyclonic and the minus sign to an anticyclonic system. The V which satisfies this equation is called the "gradient velocity."

Friction is never absent, however, in the movement of air; and consequently the force due to this should be taken into account in the above equations. The line of flow will never be quite parallel to the isobars; and the angle of inclination will be such that the force due to the pressure-gradient—which is perpendicular to the isobars—will have a component along the line of flow sufficient to overcome the force of friction.

PRESSURE DISTRIBUTION

Another description of the condition existing owing to the earth's rotation is to say that there is a region of low pressure on the left sides of two oppositely directed passing currents of air, and one of high pressure on their right sides, i. e., two oppositely directed passing currents of air will have low pressure between them if each passes on the other's left, but high pressure between them if each passes on the other's right. The airs in these currents are usually differently constituted, especially in respect to water vapor, and of different temperature. The pressure gradient is therefore in such a direction as to cause them to mix on their left sides, where the cold, denser air keeps to the earth's surface, forcing the warm and less dense air to rise. This "line type" of convective unit, in which the airs of different densities are mechanically placed, is dominant to a greater or less degree in cyclones, anticyclones, tropical hurricanes, thunderstorms and tornadoes. It is on the boundary lines between these two oppositely moving air masses, differently constituted and having different temperatures, that the centers of cyclones, tropical hurricanes and anticyclones are found. It is in the vicinity of these boundary lines, especially to the south of the cyclone center, that thunderstorms and tornadoes most frequently occur.

THE PROPAGATION OF ATMOSPHERIC DISTURBANCES

An air mass that is relatively dense for the level it occupies may not be able to sink directly to a level appropriate to its density, because of its high adiabatic rate of heating compared with the slower rate of cooling of air, latent heat of condensation considered, at a lower level that must rise to take its place. Such an air mass may, of course, be resting on the earth's surface. This air mass in motion over the earth's surface, or over an "aerial bottom" will tend to conform with the "bottom" over which it flows.

If the bottom or supporting surface be of irregular contour, like the earth's surface, this tendency to conform with it will result in a periodically alternating expansion and contraction of the air in question, with attendant changes in temperature, pressure and motion. Convective units of this type are called gusts and the wind in which they occur carries them for some distance beyond the irregularity in the bottom which caused them. If this bottom be the solid earth, there is no response by the rigid earth to the traveling gust, which ceases to exist as originally formed. Either equilibrium will be restored in uninterrupted flow over level surface or other irregularities in the bottom will superpose new gusts.

If the bottom or supporting surface be aerial and the irregularities in its contour be in the nature of pressure variations originating in the lower stratum, there will be reaction in the lower stratum to the gust initially caused by it in the upper stratum. This interaction, while probably not of sufficient magnitude continually to re-create the pressure variation in question in the lower stratum, does seem to be sufficient continually to realign the passing air currents of the lower stratum, which in turn are responsible for the pressure variation This realignment keeps up with the movement of the air in the upper of the two strata and results in a moving disturbance in the lower of these strata. This mechanism, more or less modified by atmospheric conditions, such as temperature distribution and humidity, in the lower stratum, seems in general to control the motion of traveling disturbances in the surface stratum of the atmosphere and explains the fairly well established fact of observation, viz., that all traveling disturbances in the surface stratum have, in general, the speed and direction of the air movement in the stratum immediately above. Tropical hurricanes, for example, seem to move with the antitrades, the high and low pressure areas of the middle latitudes with the upper westerlies. The same mechanism is operative in the "separation" of lows from a semipermanent low and of highs from a semipermanent high. The semipermanent high or low is a surface stratum phenomenon and has its position fixed by local conditions and must itself remain in place, but it does create the disturbance or gust in the moving air of the stratum immediately above, which is carried forward and in its turn interacts with the air of the lower stratum. The result is that a traveling high or low, as the case may be, seems to "separate" from the semipermanent high or low and continue in the general direction of the upper current. A traveling disturbance is likely to decrease in intensity when there is a southward component in its motion as a whole and to increase in intensity, when there is a northward component in its motion, in accord with the value, $2w\rho\ V \sin \lambda$, which increases with latitude.

Tests on German Blast Furnace Slags

TESTS on eight different samples of blast-furnace slag have been carried out recently by a commission appointed by the Prussian Ministry of Public Works according to the London *Iron and Coal Trades Review*. The object was to ascertain whether such slag would be a suitable material to be used as road metal and railroad ballast. The material to be tested consisted of sizes between 25 and 40 mm. (1 and 1.6 in.) 5 kg. (11 lb.) of which was placed in every case in a ball mill (but without the balls) having a corrugated drum and an inclined axis. After the drum had been slowly revolved (42 r.p.m.) for 30 minutes, the material thus treated was removed and passed over seven sieves of different sized meshes and the percentage of the residue left on each sieve noted. In order to be able to compare the wearing qualities of the slags, samples of basalt from Bavaria, of granite from Silesia, and of syenite from Saxony were tested in exactly the same way as the slags. The results compared as follows: Two of the slags were equal to basalt as regards wearing quality, two others ranked between basalt and granite and syenite and only two samples were inferior to these materials. Further researches in the laboratory and trials in the road beds are being conducted.

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